STATISTICS

OF

HYDRAULIC WORKS

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STATISTICS

OF

HYDRAULIC WORKS

AND HYDROLOGY

OF

ENGLAND, CANADA, EGYPT, AND INDIA

COLLECTED AND REDUCED

BY

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PREFACE.

A COMPILATION of that which has been done is one of the necessary aids to further doing. Its value is partly dependent on the sources, and partly on the theoretical and practical capabilities of the compiler in that special branch; its completeness is limited by the space at disposal, and the larger or smaller period over which the data extend. Finality, or perfection, cannot be attained; but if even that were possible, the end having then been reached, there would not be any future in which the book could be useful.

One may not collect facts and figures with a purpose, for fear the purpose should warp them; but, after collecting them, and after having undergone experiences connected with them of almost every sort, one is allowed to express the resulting retrospect and prospect.

In Great Britain, progress in hydraulic works has been lately confined chiefly to works of improved water supply and of sewage-irrigation. The development has now taken the permanent form of deep well-sinking for drinking-waters, of surface storage, and of tapping rivers for general purposes. These were all done, in special cases, very long ago; but the large development is a recent thing, applying to towns and villages all over the land. Sewage-irrigation in Engand is also very ancient; every Northumbrian village or group of cottages has utilised its sewage on adjoining fields for ages; but it is only latterly that this

simple and useful practice has very largely extended, after the complete and unfortunate experience of precipitation and chemical processes.

The combined effect of rational water supply and sewage utilisation has been to lower the death-rate, to diminish sickness and consequent poverty, and to encourage the life-preserving habit of personal cleanliness among the great " untubbed."

Retrogression has, however, shown itself as regards canals, which have now sunk to the lowest state. It is fully known that water-transport for heavy goods is the most economic method; but England suffers from an obstructive class—the plutocrats holding railway shares, and the railway interest, who will do their best to prevent the people from obtaining cheap transport, from a fear of diminishing their own gains.

It seems strange that, in a free country, systematic oppression should be allowed to hold its sway so long in this, and in many other things. It is one of the results of " Tradesman's Rule," under which every honest man is systematically fleeced, from cradle to grave; while the successful steady swindler is well protected by the law and the lawyers, honoured by the ignorant and the mercantile, and courted by the clergy and women.

As for Canada, the want of personal experience in that country enforces a recourse to that of friends as well as to analysis of indisputable facts.

Two things are noteworthy: the very slow development or extension of the canals and through routes, and the high expense of the works already constructed. Lands on the routes of works of public improvement are not compulsorily taken at a fair valuation, as should be the case, but the holders are allowed to block public works by choosing their own prices and terms; an arrangement unworthy of a civilised Christian country. (A

Moslem refuses all payment for his land taken for a public road, or for public wells, waterworks, or canals.) Next, there is a large amount of jobbery about public works, which could be entirely stopped. Public works loans should be absolutely safe and inalienable to other purposes; they should form a secure investment for the people of the country, who profit otherwise by the works. These two changes must evidently precede the full extension of the here proposed Canadian Ship-route from Quebec to Hudson's Bay.

In Egypt, irrigation from the Nile has for ages supplied bread to its people, but the task of supplying the insatiable Greek and Israelite is far beyond its powers. Before prosperity can revive, any attempt to make an unjust bargain or agreement must be treated as burglary; and respectable systematic swindlers, as well as all magistrates that support such claims, must be treated to expulsion or the rope. Once fairly relieved from oppression, Egypt will doubtless remodel the whole of her coarse works of irrigation on a more skilful and economic system, and remove that absurd French *barrage*.

In India, the modern canals and reconstructed old canals are far in advance of the earlier ones as regards design and quality in construction; the extension of irrigation around the old centres has also been large, involving great expenditure of money. Most of this development is due to, or centres itself round, the arrangements effected by the energetic influence and administration of General Richard Strachey, which formed a stable permanent basis of progress. The fact remains that, in or about 1869, the future of all Indian irrigation works appeared very gloomy, while the present triumph in the Indian supply of wheat to England alone affords a justification of the bolder policy carried out against much opposition.

The next probable step will be the wider extension of irrigation in India beyond the old centres, and in each and every province. The works would necessarily be small, numerous and detached, dependent on meagre rain or supply, requiring skill in detail, and involving much inconvenience in many respects. The eventual necessity for them is clear, as India cannot yet bear up against two successive famines.

The local obstruction of the covenanted Anglo-Indian civilians to such works would doubtless arrest matters; hence a necessary preliminary would be the abolition of that service, or its rigid restriction to the originally legitimate duties of collecting revenue, without retaining any further power or authority of intervention in anything.

Their law courts have already crushed the people by playing into the hands of the money-lender and the grasping landlord; their own aggrandisement has been entirely based on the crowding of servile natives to ruin each other under the legal process of "duel by lying;" their mischievous intrigues have made India uninhabitable by any independent Englishman, and warped the efficiency of every Indian official department; while their autocratic vulgarities have rendered them odious to all but themselves.

When this anomalous bureaucracy of *gharibparwars* is abolished or fang-drawn, Indian prosperity will commence, there will be less grovelling and more honest work; useful and skilful men instead of being ousted will be welcomed; and irrigation, with the consequent gradual abolition of famine, will attain its highest development without obstruction.

L. J.

ACKNOWLEDGMENTS.

THE present volume is to a certain extent an enlargement of Part II. of Hydraulic Manual and Statistics, 3rd edition, 1875, with additions of later date. (The fourth edition of 1883 is purely Manual.) The older sources of compilation have been mentioned in the preface to that book. In the additions, as well as in the older portions, much has been obtained or formed directly or indirectly by myself; other parts have been taken from the works of various authors of practical and theoretical experience; and last, when the above have been insufficient, recourse has been made to Parliamentary and Official returns and records. The last resource has been only utilised where other modes failed, for the obvious and well-known reason that such transmitted information is often wanting in accuracy.

In each case where the work of any author has been used, his name is quoted with the information, unless it happens to be a small amount appended to a larger one by some one else. The same mode has also been adopted with regard to any information, originally due to any person of experience, that may have been obtained through the medium of an Official report or return, when there mentioned.

As to the later Indian information, since 1875, this has been mostly taken from various annual records supplied from the Record Department of the India Office, chiefly the Progress Reports, Irrigation Reports, and Chemical Examiners' Reports of the various provinces of India.

In this matter, as the bulk of Reports examined was very large, and more labour than my own was devoted, I wish to mention with thanks the help afforded by the gentlemen of the Record branch of the India Office; also by those of the office of the High Commissioner for Canada.

The cost of this work, which will, it is hoped, be of benefit to engineers of the Indian Public Works Department, has, in concurrence with their wish, been liberally supported by the Government of India, for whom it was undertaken.

The projected set of coloured maps, in accordance with this book, will necessarily involve expenditure of money and time, and hence remain in abeyance for the present.

My intention was not only to put collected information into form convenient for use, but also to deduce the complete Hydrological conditions of the Gangetic basin. This failure is not due to want of labour, but of facts and data. My fragmentary results show a decrease or drying up, which is probably due to an eastward progressive movement of the centre of heavy (hill) rainfall.

With egard to the Hughli tides, personal observations of an extensive sort would be needful before new light could be thrown on the practical effect of my theories.

Possibly some future occasion may arrive for thoroughly re-investigating these interesting matters.

L. J.

LONDON, *September*, 1885.

CONTENTS.

CHAPTER I.—*GREAT BRITAIN.*

CHAPTER II.—*CANADA.*

CHAPTER III.—*EGYPT.*

CHAPTER IV.—*INDIA.*

CHAPTER V.—*CEYLON.*

CHAPTER I.

GREAT BRITAIN.

RIVER BASINS.

CANALS AND NAVIGATIONS.

STORAGE WORKS.

IRRIGATION WITH SEWAGE.

IRRIGATED CROPS.

ANALYSIS OF WATER.

GREAT BRITAIN.

RIVER BASINS.

NATURAL DIVISIONS, GROUPS AND BASINS.

(*Partly according to* JOSEPH LUCAS.)

DIVISIONS. In England and Wales.	Groups.	Basins.	Area in Square Miles.	Population in 1871.	Principal Rock Formation.
I. North-Eastern	8	23	8 695	3 547 838	Carboniferous, New Red sandstone, Oolite, and Chalk.
II. North-Western	7	40	7 866	4 089 621	Silurian, Carboniferous and New Red sandstone.
III. East-Midland	5	13	10 876	3 452 737	New Red sandstone, Oolite, Lower Green sand, and Chalk.
IV. West-Midland	4	34	10 075	2 234 350	Silurian, Old Red sandstone, Carboniferous, and New Red sandstone.
V. South-Eastern	5	31	11 226	6 818 924	Lower Wealden sand, Lower Green sand, Chalk, and Tertiary.
VI. South-Western	11	59	9 181	2 568 796	Devonian, Carboniferous, New Red sandstone, Oolite, and Chalk.
Total ...	40	200	57 919	22 712 266	
Total in 1881	...	...		25 968 286	
In North Britain.				Population in 1881	
VII. Eastern	8	28	14 996		Silurian, Devonian, Clay slate, Carboniferous, Limestone.
VIII. Western ...	8	42	11 323		Silurian, Laurentian, Mica schist, Permian, Carboniferous, Trap, Gneiss, Serpentine.
IX. Islands	4	20	3 787		Various.
Total	20	90	30 106	3 735 573	
In Ireland.					
X. Central	11	25	20 837		Carboniferous limestone Lower Silurian and Old Red sandstone.
XI. Marginal ...	4	90	8 302		Varied.
XII. Coast and Islands	5	5	3 377		Very varied.
Total	20	120	32 516	5 159 839	
Total of Great Britain	80	410	120 541	35 450 073	

ENGLAND AND WALES.

Groups.	Number of Basins.	Area in Square Miles.	Chief Rocks.	Annual Rainfall in Feet. Range.	Mean.
I. NORTH-EASTERN.					
1 Coquet	9	1 084	Coal measures, Millstone grit, Carboniferous limestone, and Trap......................	2·00 to 4·20	3·431
2 Tyne	1	1 130	Coal measures, Millstone grit, Carboniferous limestone......	2·00 to 4·20	3·431
3 Wear	1	456	Permian, Coal measures, Millstone grit, Carboniferous limestone.	2·00 to 4·20	3·431
4 Tees	2	785	Oolite, Lias, New Red sandstone, Coal measures, Millstone grit, Carboniferous limestone................	2·00 to 4·20	3·431
5 Esk	2	247	Oolite and Lias.	2·00 to 4·20	3·431
6 York-Ouse ...	3	3 339	Oolite, Lias, New Red, Permian, Coal measures, Millstone grit, Carboniferous limestone................	2·00 to 4·20	2·573
7 York-Derwent	1½	951	Chalk, Oolite, Lias, New Red sandstone.	2·00 to 4·20	2·573
8 Hull	3½	703	Post-tertiary, Chalk, Oolite, Lias, and New Red sandstone.........	2·00 to 4·20	2·573
II. NORTH-WESTERN.					
9 Eden	5	1 188	New Red sandstone, Permian, Millstone grit, Carboniferous limestone, Silurian....	2·50 to 6·25	3·431
10 Lake-Derwent	7	570	Coal measures, Millstone grit, Carboniferous limestone, a little Permian.	2·50 to 6·25	3·431
11 Lune	7	1 213	The same as Group 10.	2·08 to 6·25	3·431
12 Ribble	4	815	New Red sandstone, Coal measures, Millstone grit, &c..........	2·08 to 6·25	3·431
13 Mersey	4	2 535	New Red sandstone, Permian, Coal measures, Millstone grit, Carboniferous limestone, Silurian....	2·08 to 6·25	3·228
14 Conwy	12	1 277	Cambrian and Silurian.	3·33 to 6·25	—
15 Anglesey	1	268	Ditto with Carboniferous limestone...............	3·33 to 6·25	—
III. EAST-MIDLAND.					
16 Trent	1	4 052	Oolite, Lias, New Red, Permian, Coal measures, Grit, & Carboniferous limestone.	2·08 to 4·17	2·573
17 Ancholme ...	5	834	Oolite, Ancholme Chalk, Chalk, Post-tertiary.	2·08 to 4·17	2·573
18 Witham	1	1 079	Oolite, Chalk, and Fen	2·08 to 4·17	2·426
19 Nen	2	1 837	Oolite and Fen.	2·08 to 4·17	2·426
20 Bedford-Ouse	4	3 074	Chalk, Gault, Lower Green sand, Oolite, Lias, and Fen.	2·08 to 4·17	2·426

ENGLAND AND WALES.

Groups.	Number of Basins.	Area in Square Miles.	Chief Rocks.	Annual Rainfall in Feet. Range.	Mean.
IV. WEST-MIDLAND.					
21 Dovy	12	1 118	Silurian.	3·33 to 6·25	—
22 Towy	14	1 936	Coal measures, Millstone grit, Carboniferous limestone, Old Red, Silurian.	3·33 to 6·25	3·846
23 Wye	7	2 671	Oolite, New Red, Coal measures, Millstone, Carboniferous limestone, Old Red, Silurian.	2·08 to 6·25	—
24 Severn	1	4 350	Oolite, Lias, New Red, Permian, Coal, Grit, Carboniferous limestone, Old Red, Silurian	2·08 to 6·25	—
V. SOUTH-EASTERN.					
25 Arun	9	1 422	Tertiary, Chalk, Upper Green sand, Gault, Lower Green sand, Weald clay, and Lower Wealden sand.	2·08 to 3·33	—
26 Medway	3	1 210	Tertiary, Chalk, and Wealden.	1·83 to 2·60	—
27 Thames	3	5 244	Tertiary, Chalk, Upper Green sand, Gault, Lower Green, Oolite, Lias.	1·83 to 2·60	2·047
28 Blackwater	12	1 869	Post-tertiary, Tertiary, Chalk.	1·83 to 2·60	—
29 Yare	4	1 481	Post-tertiary and Chalk.	1·83 to 2·60	—
VI. SOUTH-WESTERN.					
30 Bristol-Avon	2	997	Oolite, Lias, Carboniferous limestone, and New Red sandstone.	2·08 to 3·33	—
31 Parret	5	1 075	Oolite, Lias, New Red sandstone, and Devonian.	2·08 to 3·33	—
32 Taw	5	889	New Red sandstone, Carboniferous limestone, Devonian, Dartmoor granite.	3·33 to 6·25	—
33 Camel	6	549	Carboniferous, Devonian, and some Granite.	3·33 to 4·17	—
34 Fowey	9	544	Devonian and Granite.	3·33 to 4·17	—
35 Tamar	9	858	Carboniferous, Devonian, and Dartmoor granite.	3·33 to 6·25	—
36 Ex	4	998	New Red, Devonian, Carboniferous, and Granite.	3·33 to 6·25	2·81
37 Axe	7	467	Chalk, Oolite, & Lias.	2·50 to 3·33	—
38 Salisbury-Avon		1 438	Tertiary, Chalk, and Oolite.	2·50 to 3·33	2·513
39 Test	6	1 232	Tertiary, Chalk, Upper Green sand, Gault, Lower Green sand...	2·50 to 3·33	2·513
40 Isle of Wight	1	134	Ditto and Wealden.	2·50 to 3·33	—

North Britain.

Groups.	Number of Basins.	Area in Square Miles.	Chief Rocks.	Annual Rainfall in feet. Range.	Mean.
VII. Eastern.					
1 Shin	7	2 769	Upper and Lower Silurian. Devonian, Flags, Oolite, and some Granite	2.25 to	
2 Spey	5	3 122	Silurian, Devonian, Clay-slate, some Granite and Serpentine	2.25 to	
3 Dee	4	1 806	Granite, Gneiss, Silurian, some Limestone	2.60 to	
4 Esk	4	903	Lower Devonian, Silurian, Clay Slate	2.50 to	
5 Tay	2	2 468	Gneiss, Limestone, Mica slate Devonian, Clay slate, Coal measures, some Basalt	2.50 to	
6 Forth	2	1 480	Mica Slate, Devonian, Clay slate, Coal measures, Limestone, some Basalt	2.40 to 5.00	
7 Almond	3	578	Carboniferous Limestone, Coal measures, Lower Silurian, Upper Devonian	2.00 to	
8 Tweed	1	1 870	Lower Silurian, Upper Devonian, Carboniferous, Protruding Porphyry & Granite	2.50 to	
VIII. Western.					
9 Northern	4	1 111	Silurian, Devonian, some Granite, and a little Limestone	— —	—
10 Na Shallag	8	1 492	Laurentian, Cambrian, a little Silurian, some Limestone, and Granite	— —	—
11 Coast	4	730	Lower Silurian, some Basalt, Serpentine and Granite	— —	—
12 Awe	7	1 823	Mica schist, Granite, Porphyrite, some Clay slate, and Devonian	— —	5.50
13 Long	5	936	Mica schist, Clay slate, some Cambrian and Devonian	— —	6.50
14 Clyde	2	1 858	Devonian, Carboniferous Limestone, some Trap	3.25 to 5.25	
15 Ayr	4	586	Silurian, Trap, some Carboniferous and Devonian, some Serpentine	3.70 to	
16 Nith	8	2 787	Silurian, Granite, Permian and Carboniferous	3.50 to	
IX. Islands.	Series.				
17 Shetland	1	615	Mica schist, Gneissose, Flag, Devonian, Granite Felstone, Quartz, Serpentine, Porphyry & Limestone	— —	
18 Orkneys	1	365	Upper Devonian	— —	
19 Hebrides	1	1 241	Laurentian	2.75 to 3.83	
20 Adjacent Islands	1	1 566	Skye, Mull, and Arran have Basalt, Quartz, Cambrian, Silurian, Diorite, Oolite, & Lias; Coll is Laurentian; Jura & Islay resemble Cantire generally	4.00 to 9.10	

Ireland.

	Groups.		Number of Basins.	Area in Square Miles.	Chief Rocks.
X. Central.					
North Central.	**1**	Bann	5	2 243	Basalt, Lower Silurian, New Red sandstone, some Gneiss and Felstone, Porphyry
	2	Foyle	3	1 129	Schist, Calciferous sandstone, Old Red sandstone, some Basalt and Diorite.
	3	Erne	1	1 689	Lower Silurian, Carb. limestone, Old Red sandstone, Yoredale shale, Millstone grit.
East Central.	**4**	Boyne	1	1 041	Carboniferous limestone, Yore dale shale and Lower Silurian.
	5	Liffey	1	529	As in Group **IV.** also some Old Red sandstone.
	6	Slaney	1	681	Granite, Lower Silurian, Trachyte, Lower Cambrian.
South Central.	**7**	Suir	3	3 555	Carboniferous limestone, Old Red sandstone, Lower Silurian, Yoredale shale, Millstone grit.
	8	Blackwater	1	1 285	Old Red sandstone, Carboniferous limestone, Yoredale shale, Grit, Coal measures.
	9	Lee	3	607	As in **VIII.** without Coal measures.
West Central.	**10**	Shannon	4	6 060	Carboniferous limestone, some Lower Silurian and some Old Red sandstone.
	11	Corrib-Moy	2	2 018	As in **X.** also Granite, Calciferous sandstone, Porphyry, Upper Silurian, Quartzite.
XI. Marginal.					
	12	North Marginal	12	1 036	
	13	East Marginal	20	2 188	
	14	South Marginal	12	716	
	15	West Marginal	46	4 362	
XII. Coast and Islands.			Series.		
	16	North Coast	1	327	
	17	East Coast	1	718	
	18	South Coast	1	461	
	19	West Coast	1	1 669	
	20	Islands	1	202	

England and Wales.

I. North-Eastern.

Group.		Basin.	Number on Ordnance Map.	Area in Square Miles.
1	Coquet Group.	1 Tweed (part of	i.	37
		2 Till	ii.	231
		3 Several streams	iii.	129
		4 Aln	iv.	104
		5 Coquet	v.	240
		6 Several streams	x. & xi.	55
		7 Wansbeck ...	ix.	126
		8 Blyth	xii.	131
		9 Several streams	xiii.	31
2	Tyne.	10 Tyne...........	viii.	1130
3	Wear.	11 Wear...........	xx.	456
4	Tees Group.	12 Several streams	xxi.	77
		13 Tees	xxii.	708
5	Esk Group.	14 Several streams...	xxiii.	100
		15 Esk	xxiv.	147
6	York-Ouse Group.	16 Ouse	xxxv.	1842
		17 Aire & Calder	xliii.	815
		81 Don	xlix.	682
7	York-Derwent Group.	29 Derwent	xxxvi.	794
		10 Several streams	xxxvii.	157
8	Hull Group.	21 Hull	xxxviii.	364
		22 Foulness	xxxix.	133
		23 Several streams	xl.	206

II. North-Western.

Group.		Basin.	Number on Ordnance Map.	Area in Square Miles.
9	Eden Group.	24 Several streams	vi.	21
		25 Line......... ...	vii.	104
		26 Eden	xix.	915
		27 Wampool ...	xiv.	78
		28 Waver	xiv.	70
10	Lake-Derwent.	29 Ellen	xvi.	72
		30 Derwent	xviii.	262
		31 Several streams	xvii.	11
		32 Ellen	xxv.	72
		33 Calder.........	xxvi.	28
		34 Ert	xxvii.	61
		35 Esk	xxviii.	64
11	Lune Group.	36 Several streams	xxxi.	28
		37 Duddon	xxix.	46
		38 Several streams	xxxii.	56
		39 Leven	xxx.	202
		40 Kent	xxxiii.	255
		41 Lune	xxxiv.	418
		42 Wyre	xli.	208
12	Ribble.	43 Ribble	xlii.	585
		44 Small stream	xlv.	7
		45 Douglas	xlvi.	168
		46 Several streams	xliv	55
13	Mersey.	47 Alt	xlvii.	126
		48 Mersey.........	xlviii.	885
		49 Weaver	lxxi.	711
		50 Dee	lxx.	813
14	Conwy Group.	51 Clwyd.........	lxix.	319
		52 Several...... streams...	lxviii.	39
		53 Conwy.........	lxvii.	222
		54 Several streams	lxi.	78
		56 Sciout, Gorfai	lxii.	143
		55 Sock	lxiii.	33
		57 Erch	lxiv.	55
		58 Dwyfach & Dwyfawr	lxv.	48
		59 Prysor.........	lxvi.	141
		60 Artro	lxxv.	45
		61 Small streams	lxxvi.	3
		62 Mawddach...	lxxvii.	151
15		63 Anglesey group...	lx. to lvi.	268

England and Wales.

III. East Midland.

	Group.	Basin.	Number on Ordnance Map.	Area in Square Miles.
16	Trent.	64 Trent	lxxii.	4 052
17	Ancholme Group.	65 Ancholme	l.	244
		66 Several streams	li. & lii.	161
		67 Lud	liii.	139
		68 Withern Eau ...	liv.	189
		69 Steeping ...	lv.	101
18	Witham.	70 Witham ...	lxxiii	1 079
19	Nen Group.	71 Welland...	lxxiv.	760
		72 Nen.........	lxxxiv.	1 077
20	Bedford–Ouse Group.	73 Ouse	lxxxv.	2 607
		74 Wissey ...	lxxxviii.	243
		75 Nar or Setchy	lxxxvii.	131
		76 (Part of lxxxvi.)	lxxxvi.	93

IV. West Midland.

	Group.	Basin.	Number on Ordnance Map.	Area in Square Miles.
21	Dovy Group.	77 Dysynui ...	lxxviii.	64
		78 Afon Dyfi...	lxxix.	217
		79 Lery	lxxx.	34
		80 Stream	lxxxi.	24
		81 Rheidol......	lxxxii.	70
		82 Istwyth ...	xcviii.	75
		83 Wyrai	xcix.	23
		84 Arth	c.	31
		85 Aeron	ci.	52
		86 Several streams	cii.	48
		87 Teifi	ciii.	386
		88 Kevern, Gwaen	civ.	94
22	Towy Group.	89 S. Bride's Bay ...	cv.	65
		90 E. and W. Cleddau	cvi.	212
		91 Pembroke ...	cvii.	114
		92 Several streams	cviii.	61
		93 Taf	cix.	183
		94 Towy	cx.	514
		95 Gwendraeth (2) fach and fawr	cxii.	73
		96 Llwchwr ...	cxiii.	156
		97 Small stream	cxiv.	66
		98 Tawe	cxv.	106
		99 Neath	cxvi.	118
		100 Afon	cxvii.	87
		101 Ogmore......	cxviii.	114
		102 Several streams	cxx.	67
23	Wye Group.	103 Ely	cxxi.	81
		104 Taff	cxix.	198
		105 Rumney ...	cxxii.	94
		106 Ebwy	cxxiii.	94
		107 Usk	cxxiv.	540
		10 8 Several streams	cxxv.	55
		109 Wye	cxi.	1 609
24		110 Severn	lxxxiii.	4 350

England and Wales.

V. South-Eastern.

Group.	Basin.	Number on Ordnance Map.	Area in Square Miles.
25 Arun Group.	111 Arun	clxxiii.	370
	112 Worthing ...	clxxiv.	35
	113 Adur	clxxv.	160
	114 Brighton ...	clxxvi.	56
	115 Ouse	clxxvii.	205
	116 Cuckmere ...	clxxviii.	75
	117 Oldhaven ..	clxxix	121
	118 Rother	clxxx.	312
	119 Hythe	clxxxiv.	88
26 Medway Group.	120 Stour	clxxxiii.	373
	121 Small streams	clxxxii.	157
	122 Medway ...	clxxxi.	680
27 Thames Group.	123 Cray and Darent...	cxxxvi.	314
	124 Thames and Lea	cxxviii.	4 613
	125 Roding	cxxxiv.	317
28 Blackwater Group.	126 Crouch	cxxxv.	181
	127 Blackwater	cxxxi.	434
	128 Coast.........	cxxxii.	24
	129 Colne	cxxx.	192
	130 Coast.........	cxxxiii.	53
	131 Stour	cxxix.	407
	132 Gipping ...	xcvii.	171
	133 Deben	xcvi.	153
	134 Coast.........	xcv.	32
	135 Ore or Alde......	xciv.	109
	136 Minsmere ...	xciii.	34
	137 Blyth	xcii.	79
29 Yare Group.	138 Lowestoft	xci.	53
	139 Waverley and Yare	xc.	880
	140 Bure	lxxxix.	348
	141 Glaven (part of)	lxxxvi.	200

VI. South-Western.

Group.	Basin.	Number on Ordnance Map.	Area in Square Miles.
30 Bristol-Avon Group.	142 Avon	cxxvii.	891
	143 Yeo	cxxvi.	106
31 Parret Group.	144 Axe	cxlv.	101
	145 Brue	cxlvi.	197
	146 Several streams	cxlvii	80
	147 Parret	cxlviii.	562
	148 Several streams	cxli. to cxliii.	135
32 Taw Group.	149 East Lynn	cxl.	41
	150 Small streams	cxxxvii.	47
	151 Taw	cxxxix.	455
	152 Torridge ...	cxxxviii.	336
	153 Bideford Bay	clxxxv.	10
33 Camel Group.	154 Bude Bay	clxxxvi.	108
	155 Pentirepoint	clxxxviii.	8
	156 Alan or Camel	clxxxix	149
	157 Several streams	cciii.	15
	158 Small streams	ccix.	43
	159 S. Ives,	unnumbered	(18)
	160 Small streams	ccvii. and ccviii.	69
34 Fowey Group.	161 Several streams	ccx	29
	162 Several streams	ccxiii. to ccxv.	76
	163 Falmouth...	ccxii.	12
	164 Small streams	ccxi.	40
	165 Truro	cciv.	66
	166 Fal	ccv.	50
	167 Several streams	ccvi.	80
	168 Fowey	cxc.	120
	169 Several streams	cxci.	71

ENGLAND AND WALES.

SOUTH-WESTERN—*continued.*

Group.		Basin.	Number on Ordnance Map.	Area in Square Miles.
35 Tamar Group.	170	Lynher......	cxcii.	100
	171	Tamar	clxxxvii.	385
	172	Tavy and Wallcombe	cxciii.	85
	173	Plymouth... Leat......	cxciv.	23
	174	Plym.........	cxcv.	59
	175	Yealme......	cxcvi.	36
	176	Erme	cxcvii.	43
	177	Aune	cxcviii.	54
	178	Sart Point..	ccii.	73
36 Ex Group.	179	Dart.........	cxcix.	200
	180	Teign	cc.	203
	181	Stream......	cci.	11
	182	Ex	cxliv.	584
37 Axe Group.	183	Otter.........	cxlix.	82
	184	Stream	cl.	21
	185	Axe	cli.	165
	186	Char.........	clii.	39
	187	Brit	cliii.	52
	188	Bredy	cliv.	21
	189	Weymouth	clv.	87

SOUTH-WESTERN—*continued.*

Group.		Basin.	Number on Ordnance Map.	Area in Square Miles.
38 Salisbury-Avon Group.	190	Frome......	clvi.	187
	191	Piddle.. ...	clvii.	119
	192	Stour	clviii.	459
	193	Avon	clix.	673
39 Test Group.	194	Lymington	clxi.	91
	195	Beaulieu...	clxii.	52
	196	Test.........	clx.	477
	197	Itchen	clxiii.	231
	198	Hamble (1)	clxiv. and clxv.	120
	199	Hamble (2)	clxxi. and clxxii.	261
40	200	Isle of Wight	clxvi. to clxx.	134

North Britain.

VII. Eastern.

Group.		Basin.	Area in Square Miles.	Highest Altitude in Feet.
1	Shin.	1 Wick	196	—
		2 Berridale and Langwell	171	2 331
		3 Ullie	207	1 905
		4 Brora	300	2 306
		5 Shin	727	2 858
		6 Conan	700	3 426
		7 Beauley	468	3 861
2	Spey.	8 Ness	650	3 060
		9 Nairn	172	—
		10 Findhorn and Lossie	516	—
		11 Spey	1 190	4 095
		12 Deveran, &c.	594	2 377
3	[illegible]	13 Strichen-Deer	216	—
		14 Ythan	295	—
		15 Don	530	2 377
		16 Dee	765	3 924
4	Esk.	17 Blackburn & Bervie, &c.	175	—
		18 North Esk	267	2 087
		19 South Esk	266	3 750
		20 Lunan & Dighty	195	—
5	Tay.	21 Tay	2 260	3 984
		22 Eden	208	1 713
6	Forth.	23 Leven	247	1 713
		24 Forth	1 233	3 819
7	Almond.	25 Almond	132	—
		26 Leith and Esk	224	2 136
		27 Tyne & coast	222	1 732
8		28 Tweed	1 870	2 695

VIII. Western.

Group.		Basin.	Area in Square Miles.	Highest Altitude in Feet.
9	Northern.	29 Thurso & Forss	362	940
		30 Halladale & Strathie	201	1 935
		31 Naver and Borgie	308	3 164
		32 Hope and Dionard	240	3 040
10	Na Shallag.	33 More	1 492	3 015
		34 Assynt		2 543
		35 Broome		3 551
		36 Na Shallag		2 498
		37 Maree		4 000
		38 Carron		—
		39 Long and Etchaig		—
		40 Sheil and Coast	—	4 000
11	Coast.	41 Glenelg & Knoidart	730	3 360
		42 Morar and Arisaag		—
		43 Moidart		—
		44 Ardnamurchan and Morvern		2 792
12	Awe.	45 Conn & Eil	169	2 730
		46 Lochy	517	1 544
		47 Nevis	35	4 406
		48 Leven and Creran	156	—
		49 Etive	165	3 670
		50 Orchy & Awe	450	2 897
		51 Cantire	331	1 530

North Britain.

Western—*continued.*

		Basin.	Area in Square Miles.	Highest Altitude in Feet.
13	Long.	52 Fyne	936	3 708
		53 Ruel		—
		54 Eck		—
		55 Long		3 301
		56 Lomond & coast		3 192
14	Clyde.	57 Clyde	1 580	2 403
		58 Irvine & coast	278	1 542
15	Ayr.	59 Ayr & Coyl	234	1 865
		60 Doon	87	2 764
		61 Girvan	81	—
		62 Stinchar & coast	184	1 750
16	Nith.	63 Pallanton & Luce	170	1 435
		64 Cree with Bladeroch and Fleet	585	2 764
		65 Ken	365	2 618
		66 Urr	306	—
		67 Nith	427	2 231
		68 Annan, &c.	413	2 631
		69 Kirtle	80	—
		70 Esk (Solway)	441	2 269

IX. Islands.

	Basin.	Area in Square Miles.	Highest Altitude in Feet.
17	Shetlands :		
	71 Mainland	420	1 476
	72 Unst Yell, &c.	195	938
18	Orkneys :		
	73 Pomona	205	—
	74 Hoy and small islands	160	1 555
19	Hebrides :		
	75 Lewis	876	2 662
	76 North Uist	315	1 992
	77 South Uist		
	78 Barra	50	—
	79 Small islands		
20	Adjacent Islands :		
	80 Skye	558	3 220
	81 Raasay, &c.	30	1 500
	82 Rum and Eigg, &c.	36	2 867
	83 Coll and Tiree	45	—
	84 Mull	317	2 505
	85 Colonsay, &c.	22	—
	86 Jura	214	1 735
	87 Islay	112	1 157
	88 Arran	162	2 735
	89 Bute	60	—
	90 Small islands	10	—

NOTE.—*Some* of these areas are roughly estimated from the Map of River Basins of the Rivers Commission Report. The Rock-formations are in *some* cases doubtful, being taken from a Geological Map in which the colours are doubtfully rendered.

Ireland.

X. Central Large Basins.

Group		Group and Basins.	No. on Ord. Map.	Area in Square Miles.	Highest Altitude.
In the North:					
1 Bann.	1	Bann and Neagh ...	64	1 088	2 198
	2	Main	65	278	707
	3	Moyola ...	66	129	1 353
	4	Balinderry	67	166	886
	5	Blackwater	68	582	1 255
2 Foyle.	6	Foyle	61	212	865
	7	Finn	62	195	500
	8	Mourne ...	63	722	2088
3	9	Erne (flows West)	123	1 689	653
In the East:					
4	10	Boyne	159	1 041	471
5	11	Liffey	168	529	1 765
6	12	Slaney......	175	681	3 039
In the South:					
7 Suir.	13	Barrow ...	183	1 184	1 602
	14	Nore	184	977	1 012
	15	Suir.........	182	1 394	1 471
8	16	Blackwater	190	1 285	3 015
9 Lee.	17	Lee.........	228	484	1 778
	18	Glashaboy	193	58	1 028
	19	Owenna-curra......	192	65	743
In the West:					
10 Shannon.	20	Shannon...	155	4 554	341
	21	Suck	156	617	358
	22	Inny	157	487	904
	23	Fergus ...	158	402	430
11	24	Corrib......	143	1 212	2 207
	25	Moy.........	110	806	2 2[illegible]0

XI. Marginal Small Basins.

	Group and Basin	No. on Ord. Map.	Area in Sq. Miles.	Highest Altitude.
12	Northern Series:			
26	Carey and Glen Shesk	17 & 18	36	1 368
27	Bush............	16	130	1 782
28	Roe	41	150	1 774
29	Four streams	36 to 39	38	1 298
30	Faughan	40	115	2 240
31	Mull, Crana & Burnfoot	34, 35 & 9	66	1 377
32	Eleven streams ...	1, 4 to 8, 11 to 15	120	2 019
33	Swilly	51	112	940
34	Leannan	31	108	1 379
35	Five streams ...	10, 32, 33, 29, 30	22	1 546
36	Lackagh and Burn	27 & 28	55	1 177
37	Seven streams ...	2, 3, 20, 21, 24, to 26	84	2 197
13	Eastern Series:			
38	Glendun and 2 streams	42 to 44	53	1 817
39	Glenarm & 2 streams	45, 46 & 69	46	1 287
40	Larne Water & 3 streams	70 to 73	40	946
41	Lagan	74	218	1 755
42	Quoile and 2 Streams ...	75 to 77	150	608
43	Leitrim R. & 3 streams ...	78 to 81	80	1 919
44	Seven streams	82 to 88	73	2 796
45	Newry R. ...	89	119	801
46	Cully and 3 others	90 to 93	150	1 385
47	Fane	94	135	1 093
48	Glyde	95	135	1 027
49	Dee and 1 stream......	96 & 97	168	988
50	Nanny and 2 streams ...	160 to 162	129	530
51	Broad Meadow & 1 stream..	163 & 164	100	374
52	Tolka and 2 streams ...	165 to 167	72	339
53	Dargle.........	169	46	1 765
54	Vartry	170	60	2 384
55	Potters and 2 streams	172 to 174	40	962

IRELAND.

MARGINAL SMALL BASINS—*continued.*

Group and Basin.	No. on Ord. Map.	Area in Sq. Miles	Highest Altitude.
13 Eastern Series—*continued.*			
56 Ovoca	171	252	3 039
57 Owennavorra, Clonough & Sow	176 to 178	122	1 356
14 Southern Series:			
58 Ballyteige ...	179	60	428
59 Corock.........	180	56	400
60 Owenduff......	181	40	629
61 Mahon	185	43	2 597
62 Tay & Dalligan	186, 187	33	2 443
63 Colligan and Brickley ...	188, 189	56	2 387
64 Womanagh ...	191	59	782
65 Owenboy ...	230	55	645
66 Stick	231	30	336
67 Bandon	229	234	1 558
68 Argideen	232	36	1 027
69 Rowry	234	14	727
15 Western Series:			
70 Ilen	233	117	1 600
71 Leamawaddra and 2 streams	235 to 237	39	1 762
72 Owvam and 2 streams ...	225 to 227	76	2 321
73 Glengariff and 5 streams ...	219 to 224	74	2 0[illegible]4
74 Sheen	218	36	2 003
75 Roughty	217	78	1 762
76 Sneem and 2 streams ...	214 to 216	80	2 668
77 Inny and 3 others......	210 to 213	124	2 542
78 Caragh and Behy	208, 209	86	2 542
79 Laune	207	320	2 239
80 Main and 1 stream ...	197, 198	157	2 169
81 Eight streams	199 to 206	87	3 127
82 Lee and Tyshe	195, 196	47	1 062
83 Feale	194	445	1 342
84 Cooraclare ...	154	52	872
85 Creegh and 3 others......	150 to 153	77	1 282
86 Coolenagh & 2 others	147 to 149	141	920
87 Kinvarra	146	168	1 080
88 Kilcolgan ...	145	148	410
89 Clarin	144	49	371
90 Owenboliska and 4 others	138 to 142	93	932

MARGINAL SMALL BASINS—*continued.*

Group and Basin.	No. on Od. Map.	Area in Sq. Miles	Highest Altitude.
15 Western Series—*continued.*			
91 Ballynahinch & 5 streams	132 to 137	134	2 393
92 Erriff	131	68	1 691
93 Bunowen and 3 others......	127 to 130	76	2 610
94 Carrowbeg & 2 others......	124 to 126	59	957
95 Newport and 2 others	107 to 109	110	1 695
96 Owenduff	106	51	2 067
97 Owenmore ...	105	130	1 021
98 Glenamoy and 2 streams ...	98 to 100	57	1 165
99 Ballinglen and 2 streams ...	101 to 103	33	901
100 Cloonamore ...	104	51	789
101 Easky and 4 streams ...	111 to 115	81	1 778
102 Ballysadare ...	116	252	1 685
103 Garvogue ...	117	139	1 575
104 Duff and 2 streams ...	118 to 120	70	1 399
105 Drowes and 1 stream	121 & 122	114	1 233
106 Ballintra and 1 stream ...	59 & 60	50	881
107 Eask			
108 Eanywater ...	58	41	1 400
109 Oily and 1 stream......	57	46	2 219
110 Glen and 1 stream......	55 & 54	35	1 649
111 Owentocker ...	52 & 53	63	1 649
112 Owenaa and 2 streams ...	56 } 49 & 50 }	73	1 568
113 Gweebara	48	60	1 71
114 Gweedore and 1 stream ...	47 & 22	31	1 636
115 Clady and 1 stream	23 & 19	44	1 639

XII. COAST SERIES.

		Sq. Miles.
16 North Coast:		
116 28 Detached Pieces	...	327
17 East Coast:		
117 49 Detached Pieces	..	718
18 South Coast:		
118 18 Detached Pieces	...	461
19 West Coast:		
119 91 Detached Pieces	...	1 669
20 Islands:		
120 Area altogether	...	202

CANALS AND INLAND NAVIGATIONS.

THROUGH ROUTES IN ENGLAND AND WALES.

According to Messrs. E. J. LLOYD, C.E. and J. H. TAUNTON, C.E. in May, 1883.

Note.—An asterisk (*) against the name of a Navigation indicates that it is owned or controlled by a Railway Company, thus affecting the whole Route.

Note.—Draft in the dimensions of locks denotes the greatest immersion at which any craft can pass through the Navigation.

Route.	Name of Canal or Navigation.	Miles.	Size of Lock. Length.	Breadth.	Draft.
			Ft. in.	*Ft. in.*	*Ft. in.*
1 London to Liverpool (First Route.)	*Regent's	8½	90 0 by	15 0	5 0
	Grand Junction ...	101	80 0 „	14 6	4 6
	Oxford	5	No lock.		
	Warwick & Napton	15	72 0 by	7 0	4 0
	Warwick & Birmingham	22	72 0 „	7 0	4 0
	*Birmingham	15	72 0 „	7 0	4 0
	Staffordshire and Worcestershire ...	1¼	72 0 „	7 0	4 0
	*Shropshire Unions	68	80 0 „	7 6	4 0
	River Mersey	10	Open navigation		
	Total	245¾			
London to Liverpool (Second Route.)	River Thames	20	Open navigation		
	Grand Junction ...	94	80 0 by	14 6	4 6
	Oxford	24	72 0 „	7 0	4 0
	Coventry	27	72 0 „	7 0	4 0
	*Birmingham	5½	No lock		
	Coventry	5	ditto.		
	*North Staffordshire	67	72 0 by	7 0	3 6
	Duke of Bridgewater's	5¼	84 0 „	15 0	4 6
	River Mersey	15	Open navigation		
	Total	263¼			

Route.	Name of Canal or Navigation.	Miles.	Size of Lock.					
			Length.		Breadth.		Draft.	
			Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
London to Liverpool (Third Route).	River Thames	20	Open navigation					
	Grand Junction......	94	80	0 by	14	6	4	6
	Oxford	5	72	0 ,,	7	0	4	0
	Warwick & Napton	15	72	0 ,,	7	0	4	0
	Warwick and Birmingham	22	72	0 ,,	7	0	4	0
	*Birmingham	15	72	0 ,,	7	0	4	0
	Staffordshire and Worcestershire ...	23	72	0 ,,	7	0	4	0
	*North Staffordshire	55	72	0 ,,	7	0	3	6
	Duke of Bridgwater's	5½	85	0 ,,	15	0	4	6
	River Mersey	15	Open navigation					
	Total	269½						
2 London to Hull (First Route).	*Regent's	8½	90	0 by	15	0	5	0
	Grand Junction ...	96	80	0 ,,	14	6	4	6
	Grand Union	24	72	0 ,,	7	0	4	0
	Leicester & Northampton	18	80	0 ,,	15	0	3	6
	Leicester	16	70	0 ,,	14	0	3	6
	Soar	8	70	0 ,,	14	0	3	6
	Trent	100	90	0 ,,	15	0	3	6
	River Humber ...	18½	Open navigation					
	Total	289						
London to Hull (Second Route).	River Thames ...	20	Open navigation					
	Grand Junction ...	94	80	0 by	14	6	4	6
	Oxford	24	72	0 ,,	7	0	4	0
	Coventry	27	72	0 ,,	7	0	4	0
	*Birmingham	5½	No lock					
	Coventry	5½	ditto.					
	*North Staffordshire	26	72	0 by	7	0	3	6
	Trent	102½	90	0 ,,	15	0	3	6
	River Humber......	18½	Open navigation					
	Total	323						

Route.	Name of Canal or Navigation.	Miles.	Size of Lock. Length.	Breadth.	Draft.
			Ft. in.	*Ft. in.*	*Ft. in.*
3 London to Severn Ports (First Route).	River Thames	$78\frac{1}{2}$	Open navigation		
	Kennet	$1\frac{1}{2}$	120 0	by 18 0	5 0
	*Kennet and Avon...	74	75 0	„ 14 6	4 6
	*Avon to Hanham..	11	108 0	„ 18 6	4 6
	Avon Tideway	$15\frac{1}{2}$	Open navigation		
	Total	$180\frac{1}{2}$			
London to Severn Ports (Second Route).	Thames	$106\frac{1}{2}$	109 0	by 17 8	4 0
	Wilts and Berks ...	37	78 0	„ 8 0	4 0
			72 0	„ 17 6	4 0
	Thames and Severn	$20\frac{1}{2}$	86 0 Altered to 72 0	12 3	4 0
	Stroudwater	7	72 0	„ 17 6	4 6
	Sharpness Docks, Gloucester and Berkeley, Section to Sharpness	9	No lock		18 0
	Total	180			
London to Severn Ports (Third Route).	Thames	$141\frac{1}{2}$	140 0 109 0 90 0	by 22 0 „ 17 8 „ 14 0	
	Thames and Severn	$28\frac{3}{4}$	72 0	„ 12 6	4 0
	Stroudwater to Tideway	8	72 0	„ 17 6	4 6
	Total	$178\frac{1}{4}$			
London to Severn Ports (Fourth Route).	River Thames	20	Open navigation		
	Grand Junction......	94	80 0	by 14 6	4 6
	Oxford	5	72 0	„ 7 0	4 0
	Warwick and Napton	15	72 0	„ 7 0	4 0
	Warwick and Birmingham	$7\frac{1}{2}$	72 0	„ 7 0	4 0
	*Stratford-on-Avon...	$12\frac{1}{2}$	72 0	„ 7 0	4 0
	Sharpness Docks, Worcester Section	24	72 0	„ 7 0	5 6
	Severn	30	150 0	„ 30 0	6 0
	Gloucester & Berkeley to Sharpness	16	100 0	„ 24 0	6 0
	Total	224			

Route.	Name of Canal or Navigation.	Miles.	Size of Lock.			
			Length.		Breadth.	Draft.
			Ft. in.		Ft. in.	Ft. in.
4 Liverpool to Severn Ports (First Route).	River Mersey	10	Open navigation			
	*Shropshire Union...	68	80 0	by	7 6	4 0
	Staffordshire and Worcestershire ...	26½	72 0	„	7 0	4 0
	Severn	44	99 0	„	20 0	6 0
	Gloucester and Berkeley	16	100 0	„	24 0	6 0
	Total	164½				
Liverpool to Severn Ports (SecondRoute).	River Mersey	15	Open navigation			
	Duke of Bridgwater's	5¼	84 0	by	15 0	4 6
	*North Staffordshire	55	72 0	„	7 0	3 6
	Staffordshire and Worcestershire ...	21½	72 0	„	7 0	4 0
	*Birmingham	15	72 0	„	7 0	4 0
	Worcester and Birmingham	30	72 0	„	7 0	5 6
	Severn	30	150 0	„	30 0	6 0
	Gloucester and Berkeley	16	100 0	„	24 0	6 0
	Total ...	187¾				
5 Liverpool to Hull (First Route).	Leeds and Liverpool	127	70 0	„	16 0	4 0
	Aire and Calder ...	35	212 0	„	22 0	9 0
	River Ouse	8	Open navigation			
	River Humber	18½	ditto			
	Total ...	188½				
Liverpool to Hull (SecondRoute).	River Mersey	15	Open navigation			
	Duke of Bridgwater's	26¾	84 0	by	15 0	4 6
	Rochdale	33	73 0	„	14 0	4 6
	Calder and Hebble (in course of improvement)	22	53 0	„	14 0	4 6
	Aire and Calder ...	35	212 0	„	22 0	9 0
	River Ouse	8	Open navigation			
	River Humber	18½	ditto			
	Total ...	158½				

Route.	Name of Canal or Navigation.	Miles.	Size of Lock. Length.	Breadth.	Draft.
			Ft. in.	*Ft. in.*	*Ft. in.*
Liverpool to Hull (Third Route).	River Mersey	15	Open navigation		
	Duke of Bridgwater's	26¾	84 0	by 15 0	4 6
	Rochdale	1	73 0	„ 14 0	4 6
	*Ashton	6	83 0	„ 8 6	4 6
	*Huddersfield.........	19¼	70 0	„ 7 0	4 6
	*Sir John Ramsden's	3¼	53 0	„ 14 0	4 6
	Calder and Hebble	13	58 0	„ 14 0	5 6
	Aire and Calder (original improved)	35	212 0	„ 22 0	9 6
	River Ouse	8	Open navigation		
	River Humber......	18½	ditto		
	Total ...	146¾			
6 South Staffordshire Mineral District to London.	*Birmingham (average)	12	72 0	by 7 0	4 0
	Warwick and Birmingham	22	72 0	„ 7 0	4 0
	Warwick and Napton	15	72 0	„ 7 0	4 0
	Oxford	5	No lock		
	Grand Junction ...	101	80 0	„ 14 6	4 6
	*Regent's	8½	90 0	„ 15 0	5 0
	Total ..	163½			
7 South Staffordshire Mineral District to Liverpool (First Route).	*Birmingham (average)	10	72 0	by 7 0	4 0
	Staffordshire and Worcestershire ...	21½	72 0	„ 7 0	4 0
	*North Staffordshire	55	72 0	„ 7 0	3 6
	Duke of Bridgwater's	5	84 0	„ 15 0	4 0
	River Mersey	15	Open navigation		
	Total ...	106½			
South Staffordshire Mineral District to Liverpool (Second Route).	* Birmingham (average)	10	72 0	by 7 0	4 0
	Staffordshire and Worcestershire ...	1½	72 0	„ 7 0	4 0
	* Shropshire Union...	68	80 0	„ 7 6	4 0
	River Mersey	10	Open navigation		
	Total ...	89½			

Route.	Name of Canal or Navigation.	Miles.	Size of Lock. Length.	Breadth.	Draft.
			Ft. in.	Ft. in.	Ft. in.
8 South Staffordshire Mineral District to Hull.	*Birmingham (average)	27	72 0 by	7 0	4 0
	Coventry	5½	No lock		
	*North Staffordshire	26	72 0 by	9 0	3 6
	Trent	102	90 0 ,,	15 0	3 6
	River Humber	18½	Open navigation		
	Total ...	179			
9 South Staffordshire Mineral District to Severn Ports (First Route).	*Birmingham (average)	10	72 0 by	7 0	4 0
	Worcester Section...	30	72 0 ,,	7 0	5 6
	Severn	30	150 0 ,,	30 0	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0	6 0
	Total ...	86			
South Staffordshire Mineral District to Severn Ports (Second Route).	*Birmingham	7	72 0 by	7 0	4 0
	Stourbridge	7	72 0 ,,	7 0	4 0
	Staffordshire and Worcestershire ...	12	72 0 ,,	7 0	4 0
	Severn	44	99 0 ,,	20 0	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0	6 0
	Total ...	86			
South Staffordshire Mineral District to Severn Ports (Third Route).	*Birmingham	10	72 0 by	7 0	4 0
	Staffordshire and Worcestershire ...	25	72 0 ,,	7 0	4 0
	Severn	44	99 0 ,,	20 0	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0	6 0
	Total ...	95			
10 Bristol and South Coast.	Bristol and Taunton	41	No record		
	*Grand Western Canal..............	42	,,		
	Total ...	83			

CANALS AND INLAND NAVIGATIONS.

SUMMARY OF LENGTH.	England and Wales.	North Britain.	Ireland.	Total.
I. Under Independent Canal Companies	1 477¾	84½	0	1 562¼
II. Under Public Trusts	1 013¼	0	164	1 177¼
III. Controlled by Railway Companies ...	1 350¼	106	92	1 548¼
IV. Converted into Railways or Derelict...	472¼	—	—	472¼

I.—CANALS BELONGING TO INDEPENDENT CANAL COMPANIES.

Name of Canal.	Size of Craft.	Length.	By the Board of Trade.
ENGLAND AND WALES.	*Ft. in. Ft. in.*	*Miles.*	*Miles.*
Aberdare Canal, Wales..................	70 0 by 10 9	6½	7
Aire and Calder Canal	212 0 „ 22 0	80	80
Barnsley Canal, incorporated with Aire and Calder	—	—	15
Baybridge Canal	No record	3½	—
Birmingham and Warwick Junction	71 0 by 7 0	2½	—
Bradford Canal	66 0 „ 15 2	3	—
Bridgwater, Duke of, Canal	84 0 „ 15 0	39¾	39¾
Britton Canal, Wales	No record	4¼	—
Bude Canal, Devon	104 0 by 29 6 63 0 „ 14 7	35½	35½
Caistor Canal, Lincolnshire	No record	4	—
Calder and Hebble Navigation, leased to Aire & Calder Canal Co.	—	—	22
Carlisle Canal	No record	11¼	—
Chelmer and Blackwater, Essex	ditto	14	14
Coventry Canal..........................	72 0 by 7 0	32½	32½
Derby Canal..............................	90 0 „ 14 6	18	18
Driffield Canal, Yorks.	—	5½	5½
Erewash Canal	72 6 „ 14 6	11¾	8
Glamorganshire Canal, Wales	67 0 „ 10 6	25½	26½
Sharpness New Docks & Gloucester and Birmingham Navigation, including			
Gloucester & Berkeley Canal	163 0 „ 29 6 115 0 „ 29 6 81 6 „ 13 6	16	78⅓
Droitwich Canal	82 0 „ 14 6	6	
Droitwich Junction	82 0 „ 7 0	1¼	
Birmingham & Worcester Canal	71 0 „ 7 0	30	

Name of Canal.	Size of Craft.	Length.	By the Board of Trade.
	Ft. in. Ft. in.	*Miles.*	*Miles.*
Grand Junction Canal (London and Northampton)	81 6 by 14 0	135	135
Grand Surrey Canal	—	4¾	4¾
Grand Union Canal	71 0 „ 7 0	26	26
Grosvenor Canal (part)	—	—	1
Hertford Union Canal & Regent's (pt.)	90 0 „ 15 0	10¼	6
Horncastle Canal, Lincolnshire	No record	11	—
Kidwelly Canal, Wales	No record	3½	—
Leeds and Liverpool Canal	76 0 by 15 2 66 0 „ 15 2	142	144
Leicester and Melton Mowbray	70 0 „ 14 6	16	16
Leicester and Northampton Canal	88 0 „ 15 6	24	24
Leven and Hull Canal, Yorks.	72 0 „ 17 0	3	3
Liskeard and Love Canal, Cornwall	No record	5¾	—
Louth Canal, Lincolnshire	87 6 by 15 5	11¾	—
Neath Canal, Wales	No record	14	—
North Walsham and Dilham Canal	ditto	7	—
Nutbrook or Shipley Canal	ditto	4½	—
Oxford Canal	71 0 by 7 0	91	91
Penelawd Canal, Wales	No record	4	—
Portsmouth and Arundel (part) Canal	80 0 by 14 0	4	4
Rochdale Canal	73 0 „ 14 2	42	35
Saint Columb Canal	—	6	6
Shorncliffe Canal	—	30	30
Sleaford Canal Lincolnshire	60 0 „ 15 0	12¾	—
Somersetshire Coal Canal	70 0 „ 8 0	7¼	11
Staffordshire & Worcestershire Canal	71 0 „ 7 0	50	50
Stourbridge Navig. Worces. and Staffs.	71 0 „ 7 0	7	7
Stroudwater Canal	72 0 „ 17 6	8	—
Surrey Dock Canal	—	4½	4½
Tavistock Canal	74 0 „ 8 0	4	4
Thames and Medway Canal	94 8 „ 22 8	9	—
Thames and Severn Canal	86 0 „ 17 6 72 0 „ 12 3	30	30⅛
Warwick and Birmingham Canal	72 0 „ 7 0	22½	22½
Warwick and Napton Canal	72 0 „ 7 0	15	14⅜
Wey and Arun Canal	84 0 „ 14 3 81 6 „ 14 3	20	18
Wilts and Berks Canal, and North Wilts Canal	78 0 „ 8 0	68¾	68¾
Wisbeach Canal	54 0 „ 14 0 92 0 „ 12 6	5¼	5¼
Total		1 210¾	—

Name of Canal or Navigation.	Size of Craft.	Length.	By the Board of Trade.
NAVIGATIONS.	*Ft. in. Ft. in.*	*Miles.*	*Miles.*
Arun River (part of) Sussex	78 0 by 12 0	13	—
Avon River (part of) Warwick.........	80 0 " 16 5	25	—
Driffield River, Yorks	—	6¾	6¾
Medway River, Upper Navigation ...	Various	15	15
Medway River Lower Navigation ...	86 0 by 23 0	7¾	7¾
Mersey and Irwell Navigation (with Duke of Bridgwater Canal)	84 0 " 15 0	57	57
Parret Navigation, Somerset	—	16	—
Rother River, Sussex	No record	11	—
SoarRiver, or LongboroughNavigation	70 0 by 14 6	8	—
Stort River, Staffordshire	100 0 " 13 6	13½	13½
Tamar Navigation, Devonshire	No record	22	—
Trent River Navigation, Notts	90 0 by 15 0	72	72
Total of Navigations	....	267	—
NORTH BRITAIN.			
Aberdeenshire Canal	No record	19	—
Borrowstorness Canal	"	7	—
Caledonian Canal	"	23	—
Crinan Canal	"	9½	—
Glenkenn's Canal	"	25¾	—
Total............	....	84¼	—
IRELAND.			
Under Independent Companies......	—	None.	—

II. Canals and Navigations under Public Trusts.

Name of Canal or Navigation.	Size of Craft.	Length.	By the Bd. of Trade.
ENGLAND AND WALES.	*Ft. in. Ft. in.*	*Miles.*	*Miles.*
Adur River, Sussex	No record	14	—
Ancholme Navigation	70 0 by 18 0	19½	19
Arun River, Sussex	78 0 „ 12 0 79 0 „ 12 0	13¼	—
Avon, Bristol	No record	15½	—
Axe River, Somerset	ditto	9	—
Bedford Level and Ouse	ditto	135	—
Blythe River, Suffolk	ditto	9 30	—
Bourne Eare River, Lincolnshire	ditto	3½	3½
Bure or North River, Norfolk	ditto	9	9
Colne River, Essex	ditto	4½	—
Dee River, Cheshire	No locks	10	10
Exeter Canal to coast	No record	5	5
Foss Navigation, York	ditto	12½	—
Idle River, Nottingham	ditto	10	—
Ilchester and Langport Navigation, Somerset	No record	7	—
Itchin Navigation	70 0 by 13 0	14	—
Ivel River, Hertford and Bedford	ditto	11	11
Larke River, Suffolk	No locks	11	—
Lea River, Hertfordshire and branch Canals	96 0 by 20 0 96 0 „ 18 0 96 0 „ 16 0 96 0 „ 13 0	19	33½
Little Ouse, or Brandon and Waveney	—	22½	22½
Nene River	80 0 „ 14 0	50	—
Narr River, Norfolk	No record	14	—
Ouse River, Sussex	ditto	30	—
Ouse River, York	70 0 by 22 6	60	60
Ribble Navigation, Lancashire	No locks	11	—
Severn (Trust)	270 0 by 35 0 150 0 „ 30 0 100 0 „ 20 0 99 0 „ 20 0	44	44
Severn (Free)	No locks	138	—
Stour River, Essex and Suffolk	—	20	20
Thames, from London Bridge	140 0 by 22 0 109 0 „ 17 8 90 0 „ 14 6	146	—
Weaver Navigation, Cheshire	—	22	—
Welland River	No record	37	—
Wye River to Hereford (Free)	No locks	37	—

Name of Canal or Navigation.	Size of Craft.	Length.	By the Bd. of Trade.
	Ft. in. Ft. in.	*Miles.*	*Miles.*
Wye and Lugg (See Derelict)	—	—	$99\frac{1}{2}$
Wey River	No record	20	20
	Total	$1013\frac{1}{4}$	—
NORTH BRITAIN.			
Canals under Public Trusts	—	None	—
IRELAND.			
Grand Canal	No record	164	164

III. CANALS AND NAVIGATIONS OWNED OR CONTROLLED BY RAILWAY COMPANIES.

Name of Railway Company.	Name of Canal or Navigation.	Size of Craft.	Length.	By the Bd. of Trade.
ENGLAND AND WALES.		*Ft. in. Ft. in.*	*Miles.*	*Miles.*
Lancashire & Yorkshire Railway.	Manchester, Bolton, & Bury Canal	68 0 by 15 0	15	16
London & North-Western Railway.	Birmingham Canals .	72 0 „ 7 0	169	160
	Shropshire Union .	80 0 „ 15 0 80 0 „ 7 6	203	$203\frac{1}{4}$
	Lancaster Canal...	72 0 „ 14 6 66 0 „ 15 2	60	60
	Huddersfield Canal .	70 0 „ 7 0	$19\frac{3}{4}$	$23\frac{3}{4}$
	St. Helen's or Sankey Canal	No record	12	$16\frac{3}{4}$
	Newport Pagnell (Converted)	71 0 „ 7 0	3	—
	Sir John Ramsden's .	53 0 „ 14 2	$3\frac{3}{4}$	4
		Total......	$470\frac{1}{2}$	—
Manchester, Sheffield, & Lincolnshire Railway.	Chesterfield Canal .	71 0 by 6 10	46	46
	Macclesfield Canal .	82 0 „ 7 3	$26\frac{1}{4}$	$26\frac{1}{4}$
	Peak Forest Canal .	81 0 „ 8 0	21	15
	Dearne and Dove ...	57 0 „ 15 0	14	$69\frac{1}{2}$
	Stainforth & Keadby	68 0 „ 17 6	13	
	Dun Navigations ...	61 6 „ 15 3	39	
	Sheffield Canals......	61 6 „ 15 2	$3\frac{3}{4}$	
	Ashton-under-Lyne and Oldham	83 0 „ 8 9	$17\frac{1}{2}$	$17\frac{1}{4}$
		Total	$180\frac{1}{2}$	—

Name of Railway Company.	Name of Canal or Navigation.	Size of Craft.	Length.	By the Bd. of Trade.
		Ft. in. Ft. in.	*Miles.*	*Miles.*
Midland Railway.	Ashby-de-la-Zouche Canal	71 0 by 7 0	26½	30
	Oakham (Converted)	72 0 „ 14 6	24	—
	Cromford & High Peak Canal	72 0 „ 14 6 80 0 „ 7 2	18	16
		Total	66½	—
Great Western Railway.	Grand Western Canal	No record	12	12
	Bridgwater and Taunton Canal ...	60 0 by 13 9	15¼	15¼
	Kennet & Avon C. and both rivers..	120 0 „ 18 0 108 0 „ 18 6 75 0 „ 14 6	85	86½
	Stratford-on-Avon ...	71 0 „ 7 0	25½	25½
	Stourbridge Extension	71 0 „ 7 0	3	3
	Hereford & Gloucester (Converted) ...	73 0 „ 8 0	34	34
	Swansea Canal	No record	17	17
	Tone and Parret ...	—	12	—
	Monmouthshire, Brecon and Abergavenny Canals...	68 6 by 10 0	54	54
	Stover Canal, Devon	—	2	2
		Total	259¾	—
Great Eastern Railway.	Stowmarket Navigation................	76 0 by 14 6	17	16
	Lowestoft & Norwich Navigation	No record	30	30
		Total	47	—
Great Northern Railway.	Fossdyke Navigation	No record	11	10⅞
	Grantham Canal ...	91 0 by 14 6	33½	33
	Louth Navigation ...	No record	14	11¾
	Nottingham Canal .	91 0 by 14 6	15	14¾
	Witham Navigation .	74 4 „ 17 3	31	31½
		Total	104½	—

Name of Railway Company.	Name of Canal or Navigation.	Size of Craft.	Length.	By the Bd. of Trade.
		Ft. in. Ft. in.	*Miles.*	*Miles.*
North-Eastern Railway.	Hull and Leven ...	No record	12	—
	Leven	ditto	3	—
	Pocklington Canal .	60 6 by 15 0	9	9
	Market Weighton Canal	60 6 „ 16 6	11	9
	Ure Navigation......	No record	7¾	7¾
	Derwent River, Yorks...............	45 0 by 15 0	40½	38
		Total	83¼	
North Staffordshire Railway.	Newcastle-under-Lyme	No locks	3	—
	Trent and Mersey Navigation	72 6 by 14 6 70 0 „ 7 0	118	118
		Total	121	
South-Eastern Railway.	Gravesend & Rochester Canal...........	No record	6¾	6¾
Regent's Canal & Railway Company.	Regent's Canal	—	9¾	9¾
Furness Railway.	Ulverstone Canal ...	—	1¼	1¼
NORTH BRITAIN.				
North British Railway.	Edinburgh & Glasgow Union Canal	No record	32	32
Caledonian Railway.	Forth & Clyde Junction Canal	—	5	53
Glasgow and Sth. Wstrn. Railway	Glasgow, Paisley, and Ardrossan Canal...	—	11	11
—	Monkland Canal ...	—	10	10
		Total	106	—
IRELAND.				
Midland Great Western Rlwy.	Royal Canal	Total	92	92

IV. Canals and Navigations Converted into Railways or Derelict.

How Disposed of.	Name of Canal or Navigation.	Size of Craft.	Length.	By other accnts.
ENGLAND AND WALES.		*Ft. in. Ft. in.*	*Miles.*	*Miles.*
Abandoned ...	Alford Canal	No record	$6\frac{1}{2}$	$6\frac{1}{2}$
Derelict	Andover Canal	65 0 by 8 6	$22\frac{1}{2}$	$22\frac{1}{2}$
Derelict	Basingstoke Canal......	72 6 „ 14 0	$37\frac{1}{4}$	$37\frac{1}{4}$
Derelict	Combe Hill Canal......	72 0 „ 14 0	4	$3\frac{1}{2}$
Abandoned ...	Croydon Canal	—	$9\frac{1}{2}$	$9\frac{1}{2}$
Derelict	Glastonbury Canal ...	No record	$14\frac{1}{4}$	$14\frac{1}{4}$
Abandoned ...	Grosvenor Canal (part)	—	1	1
Converted......	Hereford & Gloucester	73 0 by 8 0	34	34
Abandoned ...	Kensington Canal (part)	No record	2	2
Converted......	Leominster & Hereford Canal	71 0 by 7 0	46	22
Derelict	Melton Mowbray Canal	91 0 „ 14 0	$14\frac{3}{4}$	—
Converted ...	Newport Pagnell Canal	71 0 „ 7 0	3	$1\frac{1}{8}$
Derelict	Oakham Canal (part) .	72 6 „ 14 6	24	15
Derelict.........	Portsmouth & Arundel Canal (part)	80 0 „ 14 0	$11\frac{3}{4}$	8
Converted	Somerset Canal (part)	70 0 „ 8 0	7	$7\frac{1}{8}$
Derelict	Wey & Arun Junction Canal	81 0 „ 14 3	18	18
	NAVIGATIONS.			
Derelict	Avon River (Warwick part of)	82 6 „ 15 6	$16\frac{3}{4}$	$18\frac{3}{4}$
Nearly disused	Severn River	No locks	138	—
Derelict	Wye (part of)............	—	62	—
	Total	....	$472\frac{1}{4}$	—

THE RISE AND DECLINE OF INLAND NAVIGATION.

English Canals.—Although there was in ancient times much internal navigation, it was then principally conducted on the rivers, some of which were canalised, having stanches of various sorts for maintaining a navigable depth. The canals of that time were few and small, like the Caer Dyke Canal, and the Foss Dyke Canal, improved in A.D. 1121 and 1134; and like the short canal in Cornwall, with an inclined plane, of very ancient date, perhaps pre-Roman.

The modern period of canals in England began about 1755 A.D., through the efforts of the Duke of Bridgwater and of Brindley; it continued until about 1845, when Railway Companies began to buy them up, in order to gain their traffic. The public rights to cheap transport of heavy goods by water were thus over-ridden by Acts of Parliament, obtained through the influence of those gaining by railways.

It is said that in 1840, there were about 100 canals, comprising 3000 miles of navigation, in full employment. Whereas in 1870, the aggregrate length of canals and river navigation, given by the Board of Trade, is 2 437 miles, of which 1 636 miles were under the control of railway companies, and much of the remainder blocked or left unused, as well as being out of repair and unimproved for purposes of through traffic.

Dividing this century of utilisation of canals into two parts, one before 1800, the other after it, the following were the chief canals made, in order of construction :—

Begun in	Name.	Miles.	Course.
1725	Topsham Canal ...	5	From Topsham to Exeter
1758	Bridgwater Canal	40	From the Mersey to Longford Bridge, from Longford Bridge to Manchester, and to Pennington.
1760	Sankey Canal ...	$12\frac{1}{2}$	From Mersey Navigation to Sutton Heath Mines.
1761	Newry Canal ...	—	In Ireland.
1770	Monkland Canal...	10	In North Britain.
1771	Leeds & Liverpool	130	From Liverpool to Leeds.

Begun in	Name.	Miles.	Course.
1772	Birmingham Canal	$22\frac{1}{2}$	From the Birmingham and Sheffield Canal to the Birmingham and Fazeley Canal.
1772	Stafford and Worcester	$46\frac{1}{2}$	From the Severn to the Grand Trunk Canal.
1775	Chester Canal ...	$17\frac{1}{2}$	From Chester to Nantwich.
1775	Cardiff or Glamorgan	25	From the Severn, near Cardiff, to Merthyr.
1776	Chesterfield Canal	46	From Stockwith-on-Trent to Chesterfield.
1776	Brecknock Canal	33	From Monmouthshire Canal to Brecon
1776	Dudley Canal & branches	$13\frac{3}{4}$	From the Worcester and Birmingham Canal.
1776	Dublin & Shannon Canal ...	$65\frac{1}{2}$	From Dublin to Moy on the Shannon; branches 38 miles.
1776	Loughborough Canal	$9\frac{1}{2}$	From the Trent to Loughborough.
1777	Grand Trunk	130	A part of the course from London to Liverpool, on the Trent and Mersey
1777	Erewash Canal ...	$11\frac{3}{4}$	From the Trent to the Cromford Canal.
unkn.	Bristol & Taunton Canal	41	From Taunton Bridge to the mouth of the Avon.
unkn.	Edinburgh and Glasgow	50	From Edinburgh to a junction at Falkirk with the Forth & Clyde Canal.
unkn.	Foss Dyke Canal	11	From Torksey, on the Trent, to the Witham (reconstruction).
unkn.	Grand Union	$23\frac{1}{2}$	From near Foxton, on the Leicester and Northampton Canal, to the Grand Junction Canal.
1788	Royal Irish	68	A part of the Grand Canal to the Barrow.
1789	Thames & Severn Canal	$30\frac{1}{2}$	From the Stroudwater Canal to the Thames.
1790	Coventry Canal ...	27	On the course from London to Liverpool.
1790	Andover Canal ...	$22\frac{1}{2}$	From Southampton Water to Andover.
1790	Basingstoke Canal	37	From Wye to Basingstoke.
1790	Birmingham and Fazeley	$16\frac{1}{2}$	From Coventry Canal to Birmingham Canal.
1790	Fazeley Canal......	11	Between the Grand Trunk and the Coventry Canal.
1790	Hereford & Gloucester ...	$36\frac{1}{2}$	From Hereford to Gloucester.
1790	Oxford Canal	$91\frac{1}{2}$	From the Isis, at Oxford, to the Coventry Canal.
1790	Forth and Clyde Canal	$37\frac{1}{4}$	From Glasgow to the confluence of the Carron and the Forth.

Begun in	Name.	Miles.	Course.
1793	Gloucester and Hockeril	$20\frac{1}{2}$	From Berkeley Hill, on the Severn, to Gloucester.
1793	Haslingden	13	From Bury to Church on the Leeds and Liverpool Canal.
1793	Aberdare Canal ...	$7\frac{3}{4}$	From Glamorgan to Aberdare.
1793	Grand Junction Canal	147	From Brentford to Braunston on the Oxford Canal, on the course to Liverpool, and forming a junction with the lines to Hull and Bristol.
1794	Derby Canal	9	From the Trent to Derby.
1794	Cromford Canal ...	18	From Cromford to Langley on the Erewash Canal.
1796	Grand Western Canal	42	From Topsham, at the mouth of the Exe, to Taunton Bridge.
1796	Monmouthshire Canal	$17\frac{3}{4}$	——
1796	Wyrley & Essington	$35\frac{3}{4}$	From the Fazeley Canal to the Birmingham Canal.
1797	Kingston and Leominster ...	$45\frac{3}{4}$	From the Severn to Kingston.
1797	Manchester and Oldham	18	From Rochdale Canal to Huddersfield.
1797	Montgomeryshire .	$30\frac{1}{4}$	——
1797	Shrewsbury Canal	$17\frac{1}{2}$	From Shrewsbury to the Shropshire Canal.
1797	Worcester and Birmingham...	29	From the Severn to the Fazeley and Birmingham Canal.
1798	Huddersfield Canal	$19\frac{1}{2}$	From Huddersfield to the Manchester and Oldham Canal.
1798	Neath Canal	14	From the Neath to the Aberdare Canal.
1798	Swansea Canal and branch ...	$20\frac{1}{2}$	From Swansea to Hen Noyadd.
1799	Grantham Canal ...	$33\frac{3}{4}$	From the Trent to Grantham.
1799	Lancaster Canal ...	76	From Kirby Kendall to Haughton.
1799	Warwick & Napton	15	From the Grand Junction Canal to the Oxford Canal.
1799	Warwick and Birmingham	25	From Old Birmingham Canal to the Warwick and Napton Canal.
1799	Barnsley Canal ...	18	From the Calder near Wakefield to Barnsley.

Chief Canals of the Present Century.

1800	Peak Forest.........	21	From Chapel Milton Basin to the Manchester and Oldham Canal.
1800	Thames & Medway	$8\frac{1}{2}$	From Gravesend to Rochester.

Begun in	Name.	Miles.	Course.
1801	Croydon Canal ...	$9\frac{1}{2}$	From Croydon to the Grand Surrey Canal.
1801	Grand Surrey Canal	12	From Mitcham to Rotherhithe on the Thames.
1801	Kennet and Avon	57	From the Avon to the Kennet and Newbury Canal.
1801	Wilts and Berks ...	55	From the Kennet and Avon Canal to the Thames and Isis navigation.
1802	Glenkenns Canal...	27	From Kirkcudbright to Dalry.
1802	Nottingham Canal	15	From the Trent to the Cromford Canal.
1802	Somerset coal Canal and Radstock branch	16	From the Kennet and Avon Canal to Paulton.
1803	Somerset & Dorset	42	From the Kennet and Avon Canal to the Stour.
1803	Caledonian Canal	$21\frac{3}{4}$	From the North Sea to the Atlantic.
1804	Ellesmere&Chester and branches	109	——
1804	Rochdale Canal ...	31	From the Bridgwater Canal to the Calder and Hebble navigation.
1804	Southampton & Salisbury	$17\frac{1}{2}$	From the Itchin to the Avon.
1804	Shorncliffe Canal...	18	From Hythe to the mouth of the Rother.
1805	Aberdeenshire Canal	19	From Aberdeen to the Don.
1805	Ashby-de-la-Zouche	$40\frac{1}{4}$	From Ticknall to the Coventry Canal.
1805	Leicester&Northamptonshire Union	$43\frac{3}{4}$	From Leicester to Market Harborough.
1812	Glasgow and Saltcoats	$33\frac{1}{4}$	A part of the Glasgow, Paisley and Ardrossan Canal as far as Johnstone.
1814	Regent's Canal ...	9	From Paddington to Limehouse.
1815	Portsmouth and Arundel	$14\frac{1}{2}$	From the River Arun to a bay near Portsmouth.
1829	Norwich&Lowestoft Navigation	50	Finished in 1833.
unkn.	Wey and Arun Junction	16	From the Wey to the Arun.
1834	Birmingham and Liverpool Junction	—	One of the canals finished last.

NOTE.—The discrepancies in the details are sometimes due to alterations; but all information on this subject is inexact and incomplete.

DATES OF ACQUISITION OF CANALS AND NAVIGATIONS UNDER THE CONTROL OF RAILWAY COMPANIES.

'ACCORDING TO THE STATEMENT OF THE BOARD OF TRADE.

Canal or Navigation.	Miles.	Act.	Name of Railway Company, and Conditions of Acquisition.
ENGLAND & WALES.			
1845.			
Huddersfield Canal...	$19\frac{3}{4}$	8 & 9, c. 105	Amalgamated with Lon. & N.W.
Norwich and Lowestoft Navigation	30	8 & 9, c. 45 25 & 26, c. 223	Purchased by Great Eastern.
St Helen's (Sankey Brook) Canal ...	$16\frac{3}{4}$	8 & 9, c. 117 27 & 28, c. 296	Amalgamated with the London and North-Western.
Sir J. Ramsden's Canal	4	8 & 9, c. 64	Purchased by London & N.W.
Ure Navigation	$7\frac{3}{4}$	8 & 9, c. 104	Purchased by Leeds & Thirsk, now North-Eastern.
1846.			
Ashby Canal	30	9 & 10, c. 203	Purchased by the Midland.
Birmingham Canal ...	160	2 & 10, c. 244	Guarantee in perpetuity of 4 per cent. by the London and North-Western Company.
Chesterfield Canal ...	46	9 & 10, c. 358	Purchased by Man. Shfld. & Linc.
Foss Dyke Navigation	$10\frac{7}{8}$	9 & 10, c. 71	Leased for 894 years by the G.N.
Grantham Canal	33	9 & 10, c. 155	Leased for 999 years by the G.N.
Gravesend and Rochester Canal	$6\frac{3}{4}$	9 & 10, c. 339	Amalgamated with S.-Eastern.
Ipswich & Stowmarket Navigation	16	9 & 10, c. 106 25 & 26, c. 223	Leased by the Great Eastern for 42 years.
Macclesfield Canal...	$26\frac{1}{4}$	9 & 10, c. 267	Leased in perpetuity by the Manchester, Sheffield, and Lincolnshire.
Manchester, Bolton, and Bury Canal	16	9 & 10, c. 378	Amalgamated with the Lancashire and Yorkshire.
Monmouthshire Canals	20	9 & 10, c. 371	The Canal Company became a Railway Company in 1846, and the whole Undertaking, including the Brecon and Abergavenny Canal, was vested in the G.W. Railway Company in 1880 (c. 110).
Nottingham Canal ...	$14\frac{3}{4}$	9 & 10, c. 155	Leased by G. N. for 999 years.
Peak Forest Canal ...	15	9 & 10, c. 267	Leased in perpetuity by the Man. Sheffield, & Lincoln.
Stratford-upon-Avon Canal	$25\frac{1}{2}$	9 & 10, c. 278	Purchased by the Gt. Western.
Shropshire Union Canals............	$203\frac{3}{4}$	9 & 10, c. 233 10 & 11, c. 121	Became a Railway Company in 1846, and then leased in perpetuity, under an Act of 1847, to the Lond. & N.W.

Canal or Navigation.	Miles.	Act.	Name of Railway Company and Conditions of Acquisition.
Stourbridge Extension Canal	3	9 & 10, c. 278	Purchased by Great Western.
Trent and Mersey Canals	116	9 & 10, c. 84	Amalgamated with North Staffordshire.
Witham Navigation...	31¾	9 & 10, c. 71	Leased for 999 years to G.N.
1847.			
Dearne and Dove Navigation	15	10 & 11, c. 291	Leased for 999 years by the Manchr., Shffield, & Lincoln.
Dun Navigation	39	10 & 11, c. 291	Purchased by Man. Shfld. & Linc.
Louth Navigation ...	12	10 & 11, c. 113 & 148.	Leased by Great Northern.
Market Weighton Canal	9	10 & 11, c. 216	Purchased by the N.-Eastern
Pocklington Canal ...	9½	10 & 11, c. 216	Purchased by the N.-Eastern.
Stamforth & Keadby Canal	12	12 & 13, c. 29	Purchased by the Manchester, Sheffield, and Lincolnshire.
1848.			
Ashton and Oldham Canal...............	17½	11 & 12, c. 86.	Leased in perpetuity to Manchester, Sheffield, & Lincoln.
Sheffield Canal	3½	11 & 12, c. 75	Leased for 999 years by Manchester, Sheffield, & Lincoln.
1852.			
Kennet and Avon Canals	86½	15 & 16, c. 140	Purchased by the Great Western. The Board of Trade may, under certain conditions, regulate the tolls.
1862.			
Ulverston Canal	1¼	25 & 26, c. 89	Purchased by Furness Railway Company.
Stover Canal	2	25 & 26, c. 128	Amalgamated with the Moretonhampstead and South Devon Railway Company, now Great Western.
1864.			
Grand Western Canal	12	27 & 28, c. 184	Purchased by Bristol and Exeter, now Great Western.
Lancaster Canal......	60	27 & 28, c. 288	Leased for 999 years to London and North-Western.
Newcastle-under-Lyme	2	27 & 28, c. 118	Leased in perpetuity by North Staffordshire.
1865.			
Brecon and Abergavenny Canal	34	28 & 29, c. 280 43 & 44, c. 113	Purchased by Monmouthshire, now Great Western.
1866.			
Bridgwater and Taunton Canal...	15¼	29 & 30, c. 96	Purchased by Bristol and Exeter now Great Western.
1870.			
Herefordshire and Glo'stershre Canal	34	33 & 34, c. 83	Vested in Great Western.

Canal or Navigation.	Miles.	Act.	Name of Railway Company and Conditions of Acquisition.
Cromford and High Peak Canal	16	33 & 34, c. 63	Purchased by Midland.
1872.			
Swansea Canal	17	35 & 36, c. 152	Vested in the Great Western.
1882.			
The Regent's Canal	$9\frac{3}{4}$	45 & 46, c. 262	Vested in the Regent's Canal, Dock, and Railwy Company.
Total in England and Wales	1 259		
North Britain.			
1848.			
Edinburgh & Glasgow Union Canal	32	12 & 13, c. 39	Purchased by the North British.
1867.			
Forth and Clyde Junction Canal...	53	30 & 31, c. 106	Amalgamated with the Caledonian.
Total in N. Britain	85		
Ireland.			
1845.			
Royal Canal	92	8 & 9, c. 119	Purchased by the Midland Great Western.
Total Length in Great Britain and Ireland	1 436		

Board of Trade, May, 1883.

THE CANAL COMMITTEE OF 1883.

A select committee inquired into the subject of English Canals in 1883, and obtained some valuable evidence; of which the following is an abstract :—

Edward John Lloyd, C.E., and engineering manager of canals, drew attention to existing defects; among which are :—(1) The numerous companies owning parts of a through-course or communication. (2) The different gauges of these parts in waterway and in locks. (3) The faulty construction in section of waterway from sloping sides. (4) The present sections are not economic for steam-haulage. (5) The want of systematised through tolls. (6) That the canal companies do not all supply boats and haulage. (7) That the canal companies are not forced to give sufficient statistics relating to their canals and their traffic, the speed possible, the obstructions, and the wharfage available. (8) That the amalgamation of canal companies is hindered by railway control of links, by purchase and interference. (9) Bad condition of canals owned by railway companies. His proposals are :—(1) That canal boats should be 110 feet long, 11 feet wide, 6 feet deep, capacity 120 tons; and the waterways and locks altered to suit their size, being 120 × 12 × 7 feet, throughout through-courses. (2) That strictly mileage tolls should be charged on through-routes, and that these should be uniform throughout a route.

William Brown Clegram, C.E., and engineering manager of canals, recommended:—(1) Such a general improvement of canals as would enable boats of 40 tons of cargo to pass through all the waterways of the kingdom. (2) The locks to be 70 feet long, 7 to 8 feet wide, depth on sill of 5 to 6 feet. (3) That canals in a defective or imperfect state should be transferred to effective companies. (4) That all canals be emancipated from the control of railway companies. (5) That some public authority should be allowed to have compulsory powers in these matters of transfer.

John Hooke Taunton, C.E., and engineering manager of canals, represented the inefficiency of some canals, the want of capital

for carrying out repairs and improvements, and the loss of traffic owing directly to railway competition.

Leveson Harcourt, C.E., of experience in hydraulic matters, says that:—(1) The want of statistical information prevents improvement from being estimated; that an investigation is necessary. (2) Thinks that all the canals should be under one administration) Considers there are difficulties in the way of State purch of the canals.

James Abernethy, C.E., of experience in canal matters, recommended that:—(1) Canals should in any through-route follow the pattern of the Aire and Calder Canals. (2) That on through-routes enlarged locks be made to accommodate vessels of 150 to 200 tons. (3) That with steam haulage the times of delivery of goods should be regulated. (4) That the canal banks would require protection against waste. (5) In some instances recommends inclined planes or vertical lifts. (6) He considers restrictions and regulations in some cases necessary for the protection of the public; also that there should be compulsory sale of canals owned by railway companies. (7) Advocates th urchase and administration of the canals by the State. (8) M ns that some canals earn large dividends.

William Hamond Bartholomew, C.E., managing engineer of canals, noticed:—(1) The undue expense involved in bringing canal cases before the Commissioners in London. (2) He considers the cheapest haulage is that by steam tugs carrying cargo. (3) That canals require improvement generally before adopting steam-haulage. (4) That railway influence prevents amalgamation of canal companies. (5) Suggests that canal leases should provide for compulsory purchase at the end of lease, so as to facilitate amalgamations. (6) Notices the need of authority for enforcing through rates on any intermediate links of canal. (7) Recommends compulsory arbitration in most matters in preference to compulsory action of the Board of Trade.

Francis Reubillac Conder, C.E., of canal experience, thinks that:—(1) About £6 000 per mile of canal should be spent on improvements. (2) That the locks on the Grand Junction

Canal, 88 × 15, should be generally adopted; the depth increased to 7 feet. (3) That the State should not purchase the canals, but should remove impediment to their use. (4) Suggests a permanent scientific commission to deal with the subject. (5) Mentions the need of full statistics of canals published by authority. (6) Believes in the obstructive action of railway companies. (7) Necessity for full report in detail by competent engineers as to the whole of the internal navigation of the country. (8) Proposes 100-ton boats and endless chain haulage on through-routes; but considers small canals and small boats sufficient for agricultural districts. (9) Believes in compelling railway companies to keep their canals open for traffic even when worked at a loss. (10) Considers that the restoration of canal traffic is necessary to the maintenance of inland manufactures.

Fred. Morton, railway and canal carrier, of large experience, mentions that:—(1) Under the present unfavourable conditions of comparison, the cost of haulage for long distances by canal is greater than by railway; but for short distances it is less. (2) That canals have a great advantage in a continuous siding. (3) That there are great difficulties about tolls for through traffic. (4) That if 80-ton boats be adopted on through routes, the canal traffic will be very large, much time will be saved, and the cost of transit will be reduced. (5) That if boats of 200 tons were used through, the cost of transit would be further reduced. (6) That putting canal boats to discharge into vessels in port effects great economy. (7) The improvement of the canal system would benefit British manufacturers greatly. (8) He proposes that powers should rest with the Railway Commissioners as to canal matters.

General F. Rundall, of canal experience, suggests as arrangements for main routes, adaptation to steam haulage, and boats from 200 to 300 tons; locks 150 × 20, with 8½ feet depth on sill; a single control, uniform mileage tolls at a low rate, and, if necessary, purchase and administration by the State.

James Allport, railway director, believes that:—(1) In conveying coal, canal through-routes could not at all compete with railways. (2) That truck-loads are more convenient than boat-loads of coal. (3) That the interest of the public is, with the railways,

not with the canals. (4) That the canal interest should be left to take care of itself. (5) That expenditure on through routes of canals would be very wasteful. (6) That, besides coal, all heavy goods and raw material can be more cheaply conveyed by railway than by canal on long through routes. (7) That railway companies would be wise to sell such canals as they have bought at the price of purchase. (8) That the disadvantage of canals consists in the necessity for locks, and the consequent obstruction of traffic; that lifts or inclined planes have little advantage over locks. (9) That canals are good for short distances and for places unaccommodated with railways.

The bulk of evidence was to the effect:—(1) That canal transport is far cheaper for all heavy goods, on canals in suitable condition than on railways. (2) That the time of transit would be about the same. (3) That the emancipation of English canals from the control of the railway interest was very desirable. (4) That amalgamation of canal companies, improvement of waterways, and uniform mileage rates, were necessary. (5) That State or Municipal control would be necessary to prevent financial mismanagement, and to protect the public against the tyranny of vested interests, that might repeat itself in another form.

The results that might have been effected by the Committee:—(1) To declare that the compulsory purchase of all through canals, at original prices, was necessary. (2) To advise the creation of special Government funds for purposes of canals. (3) To recommend that all canals be placed under public trusts, or assigned to local boards or companies in trust. (4) To advise the construction of eight or nine enlarged through-routes, as soon as the details were determined by a conference of experts.

The actual results were, to do nothing at all; the treatment being parallel to that in the case of the water-companies, and many other cases of oppression under unjust free contract; that is, in favour of the plutocrats and to the detriment of the public. Such neglects can only culminate in mob-rule.

STORAGE WORKS.

THE PRINCIPAL STORAGE WORKS IN GREAT BRITAIN IN 1881.

Mostly according to GEORGE USILL, C.E.

Place and County.	Owners.	Date.	Cost of Works. £	Engineers' Names.	Distance to source. Miles.	Supply to: Population, Number.	Supply to: Houses, Number.	Storage effected: Capacity in Cubic Feet.	Storage effected: Area in Acres	Storage effected: Supply for Days.
Aberdare, Glamorgan...	Mixed	1859–74	100 000	W. Williams	2 & 4	32 000	6 000	7 520 000	7	60
Aberystwith, Cardigan	Corpor.	1881	16 000	T. S. Stooke	16	7 800	1 500	160 000	11	225
Ashton-under-Lyne, Lancashire	Comm.	1836–80	243 000	N. Brown	2, 4 & 7	112 000	23 000	87 120 000	83	200
Bacup, Lancashire ...	W.Comp.	1855	25 000	J. T. Mawson	1	8 500	1 889	4 160 000	9	120
Barrow-in-Furness, Lan	Corpor.	1866–78	118 384	F.C.Stileman	7	40 000	6 969	77 440 000	47	—
Bath, Somerset.	Corpor.	1846–70	126 000	Manner	$3\frac{1}{2}$ & 7	55 000	8 500	1 618 240	$3\frac{1}{4}$	—
Blackpool, Lancashire...	W.Comp.	1861	177 814	J. B. Foster	3, 6 & 11	40 000	7 187	41 600 000	—	112
Boston, Lincolnshire ...	W.Comp.	1850	30 000	T. Hawksley	12	16 500	—	12 073 000	38	250
Bradford, Yorkshire ...	Mixed	1854(?)	1 678 000	W. R. Binnie	11 & 18	—	—	180 800 000	176	140
Burnley, Lancashire ...	Corpor.	1819–79	108 424	J. Emmett	4	64 320	12 250	32 640 000	—	—
Bury, Lancashire ...	Corpor.	1853–80	358 954	T. Hawksley	16	100 000	25 000	103 250 000	154	100
Cannock, Staffordshire	W.Comp.	1879	719 000	W. Vawdrey	2	—	—	Incomplete	—	—
Cardiff, Glamorgan......	W.Comp.	1850–65	120 000	J. Simpson	4	80 000	13 000	13 536 000	20	100
Carlisle, Cumberland ...	W.Comp.	1848	42 000	J. Simpson	1	35 000	7 596	460 000	—	3
Carmarthen, Carmar....	Corpor.	1838–79	4 350	R. Evans	$\frac{1}{2}$ & 1	8 000	1 300	1 872 000	4	65
Cockermouth (urban), Cumberland	Board	1863	12 000	J. Lawson	8	6 500	1 300	Natural lake	448	60
Cockermouth (rural), do.	Rural S.A	1879	13 000	Pickering	18	14 000	2 333	Natural lake	648	60
Coventry, Warwickshire	Corpor.	1850	36 833	T. Hawksley	1	38 000	8 000	—	—	3
Durham	W.Comp.	1866–80	517 977	T. Hawksley	2 & 19	107 925	21 585	158 240 000	132	240

Place and County.	Owners.	Date.	Cost of Works. £	Engineers' Names.	Distance to source. Miles.	Supply to: Population, Number.	Supply to: Houses, Number.	Storage effected: Capacity in Cubic Feet.	Storage effected: Area in Acres	Storage effected: Supply for Days.
Eastbourne, Sussex ...	W.Comp.	1859–81	80 000	G. Wallis	1	20 000	3 000	800 000	—	7
Glastonbury, Somerset	Corpor.	1873	1 500	J. Day	$\frac{3}{8}$	3 000	70	23 200	—	8
Glossop, Derbyshire ...	Corpor.	1854–65	21 000	Blackburne	$1\frac{1}{2}$	10 000	2 000	3 315 200	11	100
Gloucester, Gloucester.	Corpor.	1855	61 000	J. Bateman	5	26 000	5 000	20 800 000	25	125
Gorton, Lancashire ...	Corpor.	1851	—	J. Bateman	1	35 000	8 000	—	—	—
Halifax, Yorkshire ...	Corpor.	1848–80	650 000	J. Bateman	16	72 000	1 600	215 680 000	250	180
Harrogate, Yorkshire ...	W.Comp.	1846–80	52 000	J. Thomas	6	10 655	2 131	12 800 000	26	320
Haslingden, Lancashire	W Comp.	1853	93 000	J. Cartwright	7	9 000	1 650	145 600 000	1300	150
Hastings, Sussex... ...	Local Bd.	1832–80	—	Several	3	30 000	5 500	7 200 000	16	75
Hereford, Herefordshire	Corpor.	1855	12 000	G. Cole	1	14 000	3 000	640 000	$1\frac{3}{4}$	6
Heywood, Lancashire	W.Comp.	1846	125 000	J. Diggle	5	41 000	10 000	30 400 000	50	100
Huddersfield, Yorkshire	Corpor.	1845–71	750 000	T. Hawksley	3 to 8	102 000	20 400	72 480 000	158	300
Hyde, Cheshire	Local Bd.	1870	27 700	J. Mitchell	$1\frac{1}{4}$	28 000	5 380	—	5	—
Ipswich, Suffolk	W.Comp.	1855	75 000	G. Horwood	—	44 500	—	80 000	—	3
Keighley, Yorkshire ...	Local Bd.	1876	223 800	Maclean	7	20 000	5 520	34 400 000	66	—
Lancaster	Local Bd.	1852–80	—	R. Rawlinson	9	—	4 462	—	60	92
Leicester	Corpor.	1853–70	400 000	T. Hawksley	11	120 000	24 500	137 600 000	200	250
Lincoln	W.Comp.	1848	24 000	T. Hawksley	2	39 500	7 275	6 080 000	25	72
Liverpool, Lancashire	Corpor.	1800–80	2 380 000	Several	25	720 000	131 280	649 120 000	601	220
Llanelly, Carmarthen.	Local Bd.	1855–78	85 500	Beardmore	2	18 000	2 500	26 880 000	30	200
Loughborough, Leicest.	Local Bd.	1869	23 500	J. Simpson	$2\frac{3}{4}$	10 000	2 000	4 640 000	9	96
Macclesfield, Cheshire	Corpor.	1830–79	70 453	S. C. Trap	3 to 4	34 100	8 500	32 320 000	49	—
Malvern, Worcestershire	Local Bd.	1852–76	17 000	J. Simpson	1	Varying	9 000	—	—	—
Manchester, Lancashire	Corpor.	1851	2 850 414	J. Bateman	20	1 000 000	200 000	727 040 000	604	142

Place and County.	Owners.	Date.	Cost of Works. £	Engineers' Names.	Distance to source. Miles.	Supply to: Population, Number.	Supply to: Houses, Number.	Storage effected: Capacity in Cubic Feet.	Storage effected: Area in Acres	Storage effected: Supply for Days.
Merthyr Tydvil Glamor.	Local Bd.	1860	83 600	T. Hawksley	7	50 000	10 000	57 600 000	120	90
Morley, Yorkshire ...	Local Bd.	1866–68	22 500	J. Lumley	4	15 000	2 000	240 000	—	9
Morpeth, Northumb. ...	Local Bd.	1853	—	R. Rawlinson	3	5 000	940	1 120 000	3	117
Neath, Glamorganshire	W.Comp.	1862–79	37 964	R. J. Ward	1	14 200	3 000	4 440 000	17	78
Normanton, Yorkshire	Local Bd.	1875	15 000	E. Lynam	3	5 000	1 000	160 000	—	30
Oldham, Lancashire ...	W. Comp.	1826–80	689 000	Several	2 & 7	155 000	33 200	195 760 000	123	150
Pemberton, Lancashire	Local Bd.	1879–80	11 000	G. Heaton	3	10 000	—	2 400 000	5	100
Penzance, Cornwall ...	T.Council	1850	17 672	J. Matthews	3	12 000	2 500	1 920 000	6	60
Preston, Lancashire ...	W.Comp.	1832–54	328 405	P. Park	9 & 20	100 000	23 180	8 347 680	26	100
Rotherham, Yorkshire...	Corpor.	1874	123 000	J. Mansergh	$3\frac{1}{2}$	35 000	6 000	24 000 000	43	200
Scarborough, Yorkshire	W.Comp.	1845	83 500	E. Felliter	$3\frac{1}{2}$ & $4\frac{1}{2}$	30 000	6 600	880 000	—	7
Sheffield, Yorkshire ...	W.Comp.	—	1 695 000	T. Hawksley	9	300 000	59 483	320 000 000	460	—
Southport, Lancashire...	W.Comp.	1854–70	182 500	T. Hawksley	9	42 000	7 700	160 000	300	1
Tenby, Pembrokeshire	Corpor.	1847	—	R. Hassard	$\frac{1}{2}$ & $2\frac{1}{2}$	5 000	860	736 000	—	76
Walsall, Staffordshire ...	W.Comp.	1856(?)	719 000	W. Vaudrey	$10\frac{1}{2}$	179 155	35 831	29 480 000	—	—
Welshpool, Montgom....	Corpor.	1862	3 500	—	$1\frac{1}{2}$	4 000	800	2 400 000	40	42
Whitehaven, Cumber....	Local Bd.	1849	40 000	T. Hawksley	$9\frac{1}{2}$	23 000	4 000	Natural lake	758	—
Wombwell, Yorkshire...	Local Bd.	1878	8 000	Landshough	—	2 450	500	480 000	4	—
Workington, Cumber....	Local Bd.	1852–79	28 000	Pickering	16	13 000	2 400	Natural lake	648	60
Wrexham, Denbighshire	W.Comp.	1868–79	57 000	Wyatt	6	—	—	6 400 000	$4\frac{1}{2}$	—
Yeovil, Somersetshire...	Corpor.	1874	20 000	T. Hawksley	9	8 000	1 364	Nat. lake (?)	—	—

Place.	Owners.	Date of Works.	Cost.	Engineers' Names.	Distance to source. Miles.	Supply to: Population, Number.	Supply to: Houses, Number.	Supply to: Factories.	Storage effected: Contents in Cubic Feet.	Storage effected: Surface Acres.	Storage effected: For Days.	Quality of Water.
Nth. Britain.												
Berwick ...	Local Bd.	—	8 218	—	3	13 500	—	—	1 392 000	308	—	bad
Dumbarton ...	T.Council	1859	15 000	—	2 & 4	11 000	700	16	8 160 000	300	204	fair
Dundee ...	Corpor.	1845	758 347	J. Watson	8 & 20	175 000	6 739	136	105 000 000	3064	213	bad
Dunfermline ...	Water Co.	1850	70 000	J. Leslie	18	18 000	—	—	28 000 000	1400	260	—
Edinburgh ...	Trustees	1819	500 000	—	Various	196 500	54 398	350	106 400 000	4552	132	fair
Galashiels ...	W. Comp.	1856	3 000	—	—	9 678	—	—	736 000	200	—	bad
Greenock ...	Trustees	1773	345 000	—	—	59 785	11 344	77	523 200 000	9850	211	fair
Hamilton ...	T.Council	1857	13 829	—	3	13 487	111	1	8 942 000	—	248	bad
Kilmarnock ...	Corpor.	1857	28 000	—	2	22 952	5 000	38	10 000 000	1250	90	fair
Paisley ...	Corpor.	1835	155 000	J. Leslie	2, 3, 8	48 257	10 460	110	128 000 000	2080	293	good
Port Glasgow	Comm.	1867	15 121	—	4	10 805	575	18	9 040 000	225(?)	117	good
Stirling ...	Comm.	1848	23 224	Gale	4	14 270	3 816	20	10 080 000	1200	126	good
Ireland.												
Belfast, Antrim	Comm.	1841–80	418 000	Lanyon	11	225 000	37 000	—	10 reservoirs	—	340	180
Dublin	Corpor.	1863	541 400	P. Neville	$24\frac{1}{2}$	318 939	25 042	—	397 267 000	—	409	200
Londonderry ...	Corpor.	1831–49	20 000	Several	1 & $1\frac{1}{2}$	30 000	4 000	—	24 000 000	—	20	90

NOTE.—In some cases of small towns, it is doubtful whether the supply is taken from surface collection, or is pumped from deep wells; as the statistics do not give the information. In other cases it is not mentioned whether the water is not partly stored in natural as well as artificial lakes. Also the storage reservoirs and distributing reservoirs are sometimes treated under one head. These defects probably existed in the original returns supplied by the townships, and printed in official papers.

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CATCHMENT DATA OF RESERVOIRS AND LAKES IN GREAT BRITAIN. (BEARDMORE.)

Large Districts.	Description.	Height above sea.	Catchment area.	Mean Discharge of year.	Mean Discharge per sq. mile.	Representing rainfall run off.	Registered rainfall per annum.	Maximum discharge per square mile.
		Feet.	Sq. miles.	c. f. p. s.	c. f. p. s.	Inches.	Inches.	c. f. p. s.
Bann and Lough Neagh, at Weir	Hilly	46 to 1765	22 205	3319	15·8	21·44	27·44	5·00
Brosna, at Ferbane Bridge	Hilly	152 to 1054	446	736	1·65	22·38	36·70	8·91
Robe, Mayo, at Ballinrobe	Flat	100 to 370	109	235	2·15	29·14	49·25	17·62
Loch Lubnaig	Precipitous	400 to 2500	70	417	5·27	81·33	70·6	78·63
Loch Katrine	Precipitous	400 to 2500	72	436	6.09	81·70	103·3	34·92
Small Hill Districts.								Storage. Millions of cubic feet.
Bann Reservoirs ...... 1838 ...	Hilly	400 to 2800	5·15	18·21	3·50	48·	72·	56·0
Greenock .... 1828 ...	Flat Moor	512 to 1000	7·88	23·61	3·29	41·	60·	38·
Glencorse Pentland	Precipitous	734 to 1600	6·00	10·	1·66	22·3	37·	7·66
Belmont .... 1843 ...	Moorland	850 to 1600	2·81	10·5	3·74	50·7	63·4	26·8
Rivington Pike .... 1847 ...	Various ...	800 to 1545	16·25	48·0	2.94	40·	55·5	29·6
Turton and Entwistle ... 1836 ...	...	500 to 1300	3·18	9·61	3·02	41·	46·2	31·43
Ashton .... 1844 ...	...	800	0·59	60·78	1·09	15·5	40·0	21·0
Bute .... 1826 ...	...	200 to 350	7·80	13·65	1·75	23·9	45·4	...
Bolton	...	800 to 1600	0·80	1·67	2·09	32·7	46·0	26·6
Brockburn, Glasgow ... 1852 ...	...	400 to 800	4·30	3·49	0·79	47·4	60·4	...

The storage effected by these reservoirs is in millions of cubic feet per square mile of catchment.

Data of some Reservoirs, according to Heywood.

Name of Reservoir.	Description of dam.	Surface of Reservoir.	Contents of Reservoir.	Maximum depth of water.	Maximum height of dam.	Engineer.
		Square miles.	Millions of cubic feet.	Feet.	Feet.	
Woodhead	Earth.	0·21	198	72	90	F. Bateman.
Torside	"	0.25	236	84	100	"
Rhodeswood	"	0·08	80	68	80	"
Arnfield	"	0·06	33·6	52	67	"
Hollingworth	"	0·02	11·7	52	70	"

IRRIGATION.

LIST OF URBAN DISTRICTS IN ENGLAND AND WALES DISPOSING OF SEWAGE BY IRRIGATION,

ACCORDING TO THE PARLIAMENTARY RETURN OF 21st MARCH, 1876; WITH ADDITIONS.

County.	District.	Population.	Stream receiving effluent.	No. of years in operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
Bedford	Bedford	16 851	The Ouse	7	6 997	2 627	None	—	See competition lists for details.		Corporation; Local Rates
Berks	Maidenhead...	6 173	All absorbed	5	unknown	516	None	—	—	—	Urban San. Auth.; Rates.
Berks	Reading	32 314	The Kennet	—	234 917	115	Bakeries Ironworks Tannery Breweries Gasworks	—	See competition lists for details.		Corpor. and Mr. Benyon
Chester	Altrincham ...	8 478	Brooks	5	3 000	134	None	55;	flow;	peaty	Urban San. Auth.; Rates.
Chester	Crewe	20 000	The Weaver	2	45 000	5 368	None	—	—	—	Urban San. Auth.; Rates.
Cumberland.	Carlisle	31 049	The Eden	16	nil	nil	Dyeworks Textile Engines	60;	flow;	gravelly	No expenses.
Cumberland.	Cleator Moor	8 000	The Keckle	$3\frac{1}{2}$	35	2	None	40;	flow;	clayey	Urban. San. Auth.; Rates.
Cumberland.	Cockermouth	5 115	All absorbed	—	nil	nil	None	16;	flow;	gravelly	No expenses; land hired and sublet.

County.	District.	Population.	Stream receiving effluent.	No. of years in operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
Cumberland	Penrith	8 317	The Eamont	—	nil	nil	None	80;	flow;	gravelly	No expenses.
Dorset	Dorchester	6 915	The Frome	—	nil	nil	None	—	—	—	No expenses.
Essex	Chelmsford	9 500	The Chelmer	10	2 300	300	Breweries	70;	flow;	loamy	Urban San. Auth.; Rates.
Essex	Romford	6 335	The Rom	—	—	nil	—	120;	flow;	gravelly	No expenses.
Essex	Waltham Cross	5 197	The Lea	2	3 850	nil	Explosives Textile	—	lift;	peaty	Urban San. Auth.; Rates; Town Mead.
Gloucester	Cheltenham	41 923	The Chelt	—	18 000	785	Gasworks Breweries Skinyards	430;	flow;	clayey	Urban San. Auth.; Rates; land bought.
Hertford	Bishop Stortford	6 250	The Stort	4	7 728	575	None	—	—	—	Urban San. Auth.; Rates.
Herts	Ware	5 362	—	3	578	690	None	114;	lift;	gravelly	Urban San. Auth.; Rates; land hired and sublet.
Hertford	Watford	8 111	The Colne	4	1 400	613	None	—	—	—	Urban San. Auth.; Rates.
Kent	Tunbridge	9 000	The Medway	3	3 500	208	Breweries	—	—	—	Urban San. Auth.; Rates.
Kent	Tunbridge Wells	19 410	—	3	87 243	8 199	None	—	—	—	Urban San. Auth.; Rates.
Lancashire	Blackburn	90 000	The Darwen	3	97 750	007	Dyeworks Textile	—	flow	—	Urban San. Auth.; Rates.

County.	District.	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
Lancashire	...Chorley	18 000	The Yarrow	6	16 550	906	Dyeworks Bleaching	132	—	—	Urban San. Auth.; Rates.
Lancashire	...Ormskirk......	6 127	—	6	nil	nil	—	68	flow;	peaty	No expenses.
Lancashire	...Prescot.........	5 990	Prescot brook	2	8 268	94	None	—	—	—	Urban San. Auth.; Rates.
Lancashire	...Swinton	10 000	The Irwell	5	—	nil	None	16	flow;	clayey	Conditions unknown.
Lancashire	...Tyldesley...	8 400	Hindsford brook	5	nil	nil	None	50	—	—	No expense; Swge. assgnd.
Lancashire	...West Derby...	31 000	Mersey and Alt	3	58 147	2 545	—	—	—	—	Urban San. Auth.; Profit.
Middlesex	...Ealing	14 184	The Thames	—	11 500	375	None	—	—	—	Urban San. Auth.; Rates; Land bought.
Middlesex.	...Enfield.........	17 000	The Lea	—	nil	nil	Crapeworks Dyeworks	—	—	—	Private benevolence.
Middlesex	...Harrow	5 010	—	6	4 234	24	None	—	—	—	Urban San. Auth.; Rates.
Norfolk	......Norwich	8 400	The Yare	2	113 300	4 224	Dyeworks Breweries Bootmaking Crapeworks Mustard-works	—	lift	—	Urban San.; Auth.; Rates.

County.	District.	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
Northamptn.	Northampton	50 000	The Nene	10	70 360	nil	Tanneries Breweries Aërated waters	327	flow	—	Urban San. Auth.; Rates; Land bought.
Notts	Hucknall	7 000	The Leen	—	nil	nil	None	—	flow	—	No expenses.
Notts	Mansfield ...	11 824	The Mann	40	40 000	nil	nil	300	flow	—	No expenses.
Oxford.........	Banbury	11 718	Cherwell	12	5 500	590	Textile	136	lift;	clayey	Conditions unknown.
Oxford.........	Oxford	32 477	The Thames	—	42 500	—	None	—	—	—	Urban San. Auth.; Rates.
Salop	Wellington ...	5 600	The Tern	—	nil	nil	—	150	flow;	light	No expenses; Sewage assgnd.
Somerset	Wellington ...	6 283	The Tone	—	nil	nil	Factories	—	flow;	light	No expenses; Sewage assgnd
Staffordshire	Leek............	11 732	—	13	nil	nil	—	130	flow;	—	No expenses; Sewage assigned.
Staffordshire	Longton	20 000	The Anchor	2	nil	nil	Collieries Potteries	120	flow;	clayey	No expenses; Speculative agreement.
Staffordshire	Wolverhampton	71 500	Canals	—	38 000	4 451	Metalworks	—	—	—	Urban San. Auth.; Profit.
Suffolk	Bury St. Edmunds	14 928	—	8	1 930	336	—	—	—	—	Urban San. Auth.; Rates.

County.	District.	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Acres.	Lift.	Soil.	Authority for Expense.
Staffordshire	Wolverhampton	71 500	Canals								
Suffolk	Bury St. Edmunds	14 928	—	8	1 930	336	—	—	—	—	Urban San. Auth.; Rates.

County.	District.	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expense.
Surrey	Aldershot	11 615	Blackwater	—	—	—	—	104	See competition lists for details		Sewage assigned under agreement.
Surrey	Croydon	55 652	The Wandle	18	21 740	11 947	—		See competition lists for details.		Urban San. Auth.; Rates.
Surrey	Epsom	6 276	The Thames	4	3 626	244	None	—	—	—	Urban San. Auth.; Rates.
Surrey	Reigate	15 916	A Brook	4	3 463	440	None	—	—	—	Urban San. Auth.; Rates.
Sussex	Worthing	9 000	The sea	12	nil	nil	None	100	lift	loamy	Urban San. Auth.; Profit.
Warwick	Birmingham	366 325	The Tame	9	100 880	31 994	Metalworks Chemical Colourwrks	272	See competition lists for details		Urban San. Auth.; Rates; Land bought.
Warwick	Leamington	20 917	—	6	16 000	1 035	None	764	See competition lists for details		Corporation profit under agreement.
Warwick	Rugby	8 500	The Avon	20	5 800	344	None	78	flow	loamy	Urban San. Auth.; Rates; Land hired and sublet.
Warwick	Warwick	11 002	The Avon	8	11 000	2 067	Gelatine	100	lift	clayey	Urban San. Auth.; Rates.
Westmorelnd.	Kendal	13 500	The Kent	5	18 871	110	Textile	—	—	—	Urban San. Auth.; Rates.

County	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense. £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
Wiltshire ……[illegible]	6 839	Brooks	40	nil	nil	None	—	flow;	loamy	No expenses.
Wiltshire ……[illegible]	7 628	The Ray	4	14 434	1 662	Carriage & engines	105	—	—	Urban San. Auth.; Rates; Land bought.
Worcester …Malvern ……	[illegible] 694	Pool brook	—	Incom-plete	54	None	—	—	—	Urban San. Auth.; Rates; Incomplete.
Yorkshire……Guisboro …	5 202	Holbeck	5	1 522	nil	None	24	See competition lists for details		Private benevolence.
Yorkshire……Handsworth ..	5 783	—	14	nil	nil	None	12	flow;	clayey	No expenses.
Yorkshire……N. Bierley …	14 433	The Calder	—	—	—	Woollens	—	—	—	Profit; Incomplete.
Yorkshire……Doncaster …	18 750	—	3	20 000	332	—	305	See competition lists for details		Urban San. Auth.; Profit.
Yorkshire……Harrogate …	6 655	Oatbeck	—	11 050	582	None	—	—	—	Urban San. Auth.; Rates.
Yorkshire……Idle …………	5 700	The Aire	—	nil	nil	Woollens	—	flow	—	No expenses.
Yorkshire……Skipton ……	6 042	Ellers-becks	—	Incom-plete	—	Dyeworks		Being laid out		Profit; Incomplete.
Yorkshire……Thornton……	6 400	Thornton-beck	—	nil	nil	Woollens	—	flow	—	No expenses.
Yorkshire……Windhill ……	6 500	Bradford-beck	—	nil	nil	Woollens Dyeworks	—	flow	—	No expenses.

County.	District.	Population.	Stream of Catchment.	No. of years in Operation.	Capital Expense £	Annual Expense £	Factory, Refuse from.	Farm. Acres.	Farm. Lift.	Farm. Soil.	Authority for Expenses.
WALES.											
—	Ruthin.........	3 000	—	9	250	nil	—	112	flow	—	Land sublet.
Brecon.........	Brynmawr ...	7 000	Clydach	9	300	nil	None	150	flow	—	No annual expenses.
Denbigh	Denbigh	6 322	Henllan-Skeet	—	nil	nil	Tanneries	—	flow	varied	No expenses.
Denbigh	Wrexham	8 537	Gwenfro	4	1 000	nil	Breweries	104	See competition lists for details		No annual expenses; Land hired&sublet.
Glamorgan ...	Merthyr	55 000	The Taff	4	53 330	2 690	Ironworks	—	—	—	Urban San. Auth.; Rates.
NORTH BRITAIN.											
Aberdeen......	Aberdeen......	88 125	Dee and Coast	5	nil	nil	Not mentioned	50	—	—	Corporation; Profit.
Edinburgh ...	Edinburgh ...	235 946	Forth estuary	100	nil	nil	Not mentioned	250	—	—	Urban San. Auth.; Profit; Land let by auction.
Port Dundas		—	Clyde estuary	—	—	—	Distilleries	300	lift	—	Private owner; Profit.
Lanarkshire...	Wishaw	10 000	Clyde and Calder	—	—	50	Distilleries	30	flow	—	Private owner; Profit.

GENERAL TABULAR STATEMENT OF THE NINE

Based on the Judges' Report of the

Sewage Farms.	Area of Farm.	Irrigated Area.	Supply of Sewage from	Sewage Supply. Per Acre of Farm.	Sewage Supply. Per Acre of Irrigation.	Average Daily Supply of Sewage.	Distance to Farm.	Lift of Sewage.	Establishment of Sewage Farm.	Duration of Sewage Farm until 1879.
CLASS I.—Small.	Acres.	Acres.	Persons	Persons.		Cubic ft.	Miles	Feet	Year.	Yrs.
1 Aldershot...	104·0	99·	8 000	77	81	28 000(?) unknown.	adjoining	Flow	1864	15
2 Bedford ...	183·13	153·	18 690	102	122	152 000	1·30	21 & 13	1868	11
3 Guisbrough	24·23	16·	5 300	219	330	18 000(?) unknown.	0·50	Flow	1870	9
4 Wrexham .	104·	100·7	10 000	96	99	48 000 to 80 000	near	Flow	1869	10
CLASS II.—Large.										
5 Birmingham	271·61	252·91	112 500	444	539	480 000 and upwards.	0·25	Flow	1867	12
6 Croydon ...	455·64	320·	55 000	121	172	1233 000	0·50	Flow	1860	18
7 Doncaster .	304·82	229·42	21 000	69	92	91 000	2·00	52	1873	6
8 Leamington	764·19	161·06	23 000	30	142	100 000 to 140 000	2·25	132	1871	8
9 Reading ...	675·	76·06	33 000	51	433	80 000 to 128 000	2·43	43	1875	[illegible]

SEWAGE FARMS COMPETING IN 1879.

Royal Agricultural Society of England.

Details of Account given for	Close of the Financial year of Account, 1878.	Manager in 1879.	Resident or Working on the Farm.	Quality of Land, and	Absorption of Water by Weight.	Quality of Subsoil and	Absorption of Water by Weight.	Local disadvantages.
Years.	Date.	Name.	Persons.	Soil.	Per cent.	Subsoil.	Per cent	
None	None	Mr. Blackburn	25	Light sandy	36·2	Ferruginous gravel	—	Want of storm outlets.
1875–78	31 Dec. '78	Mr. Collett ...	28	Light sandy Loamy soil	34·7 43·5	Similar to soil	—	Sewers are liable to flooding.
1878–79	31 Dec. '78	Mr. Clarke ...	8	Clayey ... Loamy ...	54·3 49·5	Similar to soil	—	Soil unsuitable for pure filtratn.
1876–78	1 Feb.'79	Mr. Jones ...	19	Sandy&peaty Do. do.	61·5 80·0	Gravel and sand	—	None.
1878–79	31 Dec.' 78	Mr. Anscombe	28	Light peaty Stiff clayey	79·7 57·6	Gravel	—	Liable to flooding.
1878–79	25 Mar.'79	Mr. Parrott ...	94	Light peaty Gravelly Dark gravel	103·0 49·7 65·9	Yellow marl Open gravel Open gravel	25·9 13·1 9·4	Liable to excess of subsoil wtr.
1878–79	2 Feb. '79	Mr. Brundell .	44	Light sandy Light sandy Stiff clayey	24·2 28·8 47·3	Similar to soil	—	None.
1876–78	31 Dec. '78	Mr. Tough ...	46	Light sandy Stiff ...... Heavy ...	23·4 44·9 56·6	Similar to soil	—	High lift.
1877–79	29 Sep. '78	Mr. Champion	88	Light ...... Stiff	40·2 43·3	Gravel & peat Clay	32·7 46·2	350 acres are liable to flooding.

EXPENDITURE ON THE NINE SEWAGE FARMS

	For the Year ending on———.	Expenditure on Pumping or payment for Sewage.	Permanent Works.	Rent, Rates, Tithes, Taxes and Insurance.	Management.	Wages.	Steam Cultivation, Coal, Carts, &c.
		£	£	£	£	£	£
1 Aldershot	—	—	—	nil	—	—	—
2 Bedford	31 Dec. 1878	338	—	1 015	145	574	—
3 Guisbrough	31 Dec. 1878	5	—	44	—	90	—
4 Wrexham	1 Feb. 1879	—	—	476	—	459	—
5 Birmingham ...	31 Dec. 1878	—	—	†583	100	750	840
6 Croydon	25 Mar. 1879	—	414	5 208	200	2 542	161
7 Doncaster	2 Feb. 1879	350	—	952	100	722	—
8 Leamington......	31 Dec. 1878	*900	183	1 620	200	1 836	81
9 Reading	29 Sep. 1878	731	449	†528	225	1 916	153

* The Leamington tenant pays £450 of this.

GE FARMS DURING THE YEAR 1878, IN POUNDS STERLING.

Wages.	Steam Cultivation, Coal, Carts, &c.	Implements.	Seeds and Plants.	Fodder or Keep of Stock.	Live Stock.	Veterinary Expenditure, Blacksmith & Harness.	Auctioning, Advertisements and Law.	Miscellaneous.	Depreciation of Stock Valuation.	Farm Expenditure. Total.
£	£	£	£	£	£	£	£	£	£	£
574	—	—	145	175	—	—	74	118	increase	2 244
90	—	—	8	38	—	—	—	10	unmentioned	190
459	—	—	20	11	24	—	12	16	increase	1 018
750	840	125	252	651	1 081	—	—	—	increase	†4 382
2 542	161	138	121	782	1 198	133	156	44	1 071	12 163
722	—	—	128	43	769	—	—	204	275	3 191
1 836	81	168	280	976	1 538	126	—	237	7	7 252
1 916	153	—	79	1 120	321	289	—	123	increase.	†5 203

† The rent for freehold land is not included in these two cases.

INCOME OF THE NINE SEWAGE FARMS

	For the Year ending on ——	Rye-grass.	Hay.	Cereals.	Roots.	Vegetables.
		£	£	£	£	£
1 Aldershot.........	—	—	—	—	—	—
2 Bedford	31 Dec. '78	184	48	409	971	273
3 Guisbrough	31 Dec. '78	153	10	—	109	—
4 Wrexham.........	1 Feb. '79	109		52	—	316
5 Birmingham......	31 Dec. '78	790	173	—	166	550
6 Croydon	25 Mar. '79	1 200	128	172	36	376
7 Doncaster	2 Feb. '79	767		1 049	—	—
8 Leamington......	31 Dec. '78	810		958	—	371
9 Reading	29 Sep. '78	248	138	247	—	—

* Error of £60 in

E FARMS

Roots.	Vegetables.
£	£
71	273
09	—
—	316
66	550
36	376
—	—
—	371
—	—

Error of £60 in

DURING THE YEAR 1878, IN POUNDS STERLING.

Crops consumed.	Milk, Wool, Butter, and Calves.	Live Stock sold.	Sub-rents; Keep and Hire.	Miscellaneous.	Increase of Stock-Valuation.	Farming Income. Total.	Profit Credited in Accounts.	Actual Farming Profit.
£	£	£	£	£	£	£	£	£
165	—	—	120	30	138	2 338	loss 244	94
—	—	—	—	—	none	272	77	82
451	115	—	21	10	56	1 130	112	112
—	1 271	843	—	99	1 555	5 447	1 065	1 065
—	2 394	914	364	87	depr.	5 671	loss 6 497	loss 6 497
—	—	948	10 bal.	152	depr.	2 926	loss 265	loss 265
887	1 714	2 960	260	216	depr.	8 179	*417	927
—	2 166	1 207	295	—	1 775	6 076	873	unestimated

Leamington accounts.

TABLE OF RATES PER ACRE OF EXPENSE AND PROFIT

Sewage Farms.	Area of Farm used in Calculation.	Weekly wages for labour in 1878.	Expenditure on Farm before 1878.	Valuation of Stock and Plant in 1878.	Rent, Taxes, Tithes and Insurance in 1878.	Management & Wages in 1878.
	Acres.	£	£ Per acre.	£ Per acre.	£ Per acre.	£ Per acre.
1 Aldershot	*104·	—	not given.	not given.	...	...
2 Bedford	*183·13	0·70	22·656	7·508	5·543	3·926
3 Guisbrough ...	* 24·23	0·90	not given.	none.	1·816	3·714
4 Wrexham	*104·	0·75	8·990	23·183	4·577	4·413
5 Birmingham ...	271·62	0·90	50·473	16·340	†2·146 incomplete.	3·129
6 Croydon	*455·64	0·90	12·681	10·980	11·430	6·018
7 Doncaster	*304·82	0·95	16·895	16·377	3·123	2·697
8 Leamington	*764·19	0·70	9·253	10·860	2·120	2·664
9. Reading	675·	0·90	12·025	15·916	†0·782 incomplete.	3·176

* These areas are employed to reduce the rates in the Report of the Judges;

† Accounts incomplete, as complete

NOTE.—The economy effected by purifying the effluent should

OF THE NINE SEWAGE FARMS, IN POUNDS STERLING.

Total Annual Expenditure in 1878.	Gross Returns in 1878.	Credited Profit in 1878.	Actual Profit in 1878.	Estimated Mean Annual Supply of Sewage.	Irrigated Area.	Amount of Sewage purified Annually per Acre of Irrigated Area.
£ Per acre.	£ Per acre.	£ Per acre.	£ Per acre.	Millions of Cubic feet.	Acres.	Cubic feet per acre.
not given.	—	Profit.	---	10	99·	101 010
12·253	12·767	Loss 1·332	Profit. 0·514	55	153·	359 477
7·842	11·226	3·178	3·384	8	16·	500 000
9·788	10·865	1·077	1·077	23	100·7	228 401
†16·134	20·054	†3·920	†3·920 incomplete.	175	*252·91	691 950
26·706	12·446	Loss 14·260	Loss. 14·260	450	320·	1 406 250
10·469	9·599	Loss 0·870	Loss. 0·870	33	229·42	143 840
9·490	10·703	0·546	1·213	44	161·06	273 190
†7·708	9·002	†1·294	†1·249 incomplete.	38	76·06	499 630

for Reading they employ 645 acres in the year 1879.
rent is not debited.

be credited to the irrigation, apart from farming profit.

CAPITAL EXPENDITURE ON THE NINE SEWAGE FARMS UNTIL 1878, IN POUNDS STERLING.

	Land and Compensation	Buildings for Boilers, Engines, &c.	Engines and Pumps.	Settling Tanks and Extractors.	Main delivery Sewers.	Total Expenditure on Sewerage Works.	Farm Buildings.	Tanks and Carriers.	Preparing Land & Roads.	Drainage.	Miscellaneous.	Total Expenditure on Farm.	Total Capital Expenditure.	Valuation of Farm Stock, Plant, &c., in the years 1877	1878
	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£
1 Aldershot ...	—	—	—	—	—	not given	—	—	—	—	—	not given	6 000	not	given
2 Bedford	303	780	970	—	748	2 801	603	1 545		1 648	353	4 149	6 950	1 237	1 375
3 Guisbrough .	—	—	—	—	—	not given	—	—	—	—	—	not given	1 692	none	none
4 Wrexham ...	—	—	—	700	400	1 100	161	181	471	122	—	935	2 035	2 369	2 411
5 Birmingham .	—	—	—	—	—	not given	3 057	10 652			—	13 709	—	2 883	4 438
6 Croydon	—	538	—	1 406	—	1 944	2 218		3 560		—	5 778	7 722	6 075	5 003
7 Doncaster ...	—	—	—	—	—	18 000	1 350	—	3 800		—	5 150	23 150	5 267	4 992
8 Leamington .	—	—	—	—	—	15 500	1 546	981	3538	963	43	7 071	22 571	8 306	8 299
9 Reading	804	23 697		—	12 330	36 831	5 091	678	1 730	512	106	8 117	44 948	8 967	10 743

ABSTRACT FROM THE JUDGES' REPORT ON THE SEWAGE FARM COMPETITION, 1879.

1.—ALDERSHOT.

General Statement.—There is very little detail given of the sewage and farming operations at this place owing to the approaching termination of the tenant's lease. Before 1864 the sewage of the Camp was badly dealt with at a cost of £1 600 yearly, and the land now converted into a farm was not worth five shillings per acre.

Capital Account.—The tenant expended his own capital in creating the farm on the faith of a Government subsidy to be paid annually. The sum of £6 000 capital was spent in preparing the land, making sewage carriers, roads, tanks, farmbuildings, lodge and cottages.

Sewage.—The whole of the sewage from the Aldershot Camp passes on to the farm; the storm-water outlets are never used, so that all the liquids are employed in irrigation. The effluent water passing from the farm drains is clear, bright and inoffensive; the purification of sewage is perfectly satisfactory. The fresh sewage from the Camp, which is stronger than ordinary town sewage and refuse, is collected in subsidence tanks, of small size, on the farm, from which the liquid matter alone is allowed to flow direct on to the land. Three sludge-tanks, formed by earthen banks coated with a mixture of gravel and tar, receive the more solid matter at a lower level, as well as the flushings from the subsidence-tank. Their dimensions are $111 \times 21 \times 2\frac{1}{2}$ in feet. The sludge is allowed to drain and consolidate in them, and in certain seasons is carted on to the land. The liquid sewage runs entirely in earthcut carriers, the sides of which are protected with heaped grass sods. The land is divided into two-acre plots, which are also subdivided by subsidiary carriers. The distributing-carriers are ploughed out from time to time, when the crops are ready for the sewage.

Pumping.—Although only nine acres of the farm are not commanded by simple flow of sewage, yet pumps, a high pressure steam-engine, and engine-house have been erected at the lower part of the farm. These are, however, not only used for lifting sewage on to the nine acres, but serve for raising water from a

stream to dilute the sewage in dry weather, and enable a part of the effluent water to be again used on the land.

Drainage.—Parts of the land are under-drained to a depth of four to six feet, the drains being thirty to sixty feet apart. It appears doubtful whether more perfect drainage would not be advisable, for, after continuous wet weather, some of the farm land becomes flooded, and not only are the crops spoilt, but the fertility of the soil is much deteriorated by the flooding.

The Crops.—Crops of all sorts have been grown on this farm. Mangolds have been tried, but apparently the soil is not well suited to them. The Potatos grown are singularly free from disease: this may be due to good selection of varieties, to good management of the sewage, or to the use of gas-lime, with which the land is occasionally dressed.

The crops of the year 1879 consisted of Potatos 57¼ acres, Rye-grass 40 acres, Rhubarb 1½ acres, Cabbage plants ¼ acre; Total 99 acres. (*See Irrigated Crops.*)

Live Stock.—Until recently a large number of cows were kept on the farm by a sub-tenant; but there was only one during the past year. Four horses are also kept for farm cultivation.

Health.—The report as to residents and labourers states that they have lived free from ill-heath and epidemic disease during the fifteen years. The effluent passing into the streams is satisfactorily purified.

2.—BEDFORD.

General Statement.—The farm is held by five owners, to whom the Corporation of Bedford pays rent. Some of the land is liable to flooding from the Ouse. Irrigation is effected on 153·25 acres out of the 183·12 acres of farm. Half of the land is very unfertile but is hired at a rent about three times its just value for ordinary tillage, thus absorbing much of the fair profit from sewage farming.

Capital sunk.—The details are given in the tabular statement.

Sewerage.—The whole of the sewage of the Borough of Bedford is collected at the site of the pumping station, where the solids are screened by a grating, and a storm-overflow into the river used in times of flood. At other times the pumps lift the liquid sewage on to the farm to a height of 13 feet for 123 acres, and to 21 feet for 30·25 acres, the pumping being carried on in the day-

time only. At night the sewage is stored in the sewers. The average weight of coal used daily is 21 cwt., and the average amount of sewage pumped daily is 152 000 cubic feet. The screened sewage is pumped through an 18-inch iron main-pipe, having a 15-inch iron branch pipe leading to one part of the farm. The carriers are earthenware pipes 18 inches to 9 inches in diameter, laid in banks above the surface of the land. The distributors are earth-cut channels, ploughed or dug from time to time as required. The screened solids are used on the land.

Drainage.—Only five acres are underdrained to a depth of three feet with 2-inch pipe-drains placed 60 feet apart; the rest s drained by deep ditches round all the fields, dug as low as the outfall admits.

Crops.—A large variety of crops, partly market-gardeners', have been grown from 1875 to 1878 without very much fluctuation from year to year. The following is the acreage of each crop for the year 1878, and the average value of yield per acre :—

	Crops in 1878.	Acres	Average value per Acre.	Value of Crop.
Grass	Italian Rye grass...	24·	£7·66	£184·
	Permanent pasture	7·5	6·37	47·85
Roots.	Mangolds	35·5	13·67	485·25
	Swedes	2·5	13·38	34·70
	Carrots	8·5	15·28	129·87
	Parsnips	1·75	20·	35·
	Potatos	9·25	16·84	155·76
	Onions...	16·63	33·28	553·31
Cereals.	Wheat ...	18·	10·95	197·17
	Oats	17·	12·48	212·20
Market Garden.	Beans ...	3·87	13·11	50·
	Spring Cabbage ...	3·	11·42	34·27
	Savoys...	3·63	14·02	50·85
	Cauliflowers...	3·37	30·22	101·99
	Kidney Beans	0·25	24·96	6·24
	Celery ...	0·37	36·	13·50
	Cucumber	0·5	13·35	6·67
	Rhubarb	0·13	11·50	1·43
	Asparagus ...	0·13	56·	7·
	Prickly Comfrey ...	0·25	10·	2·50
	Currant Trees	0·5	—	—
	New Asparagus ...	1·25	—	—
	Total	157·81	—	2 309·62

A Meadow of $22\frac{1}{2}$ acres is also sublet at an annual rent of £119.

The following remarks apply chiefly to the crops of the year 1879.—(*See Irrigated Crops.*)

Rotation of cropping cannot be carried out regularly, on account of some part of the farm being liable to flooding; but on part of the land the following is the rotation:—1st, rye-grass for two years; 3rd year, mangolds; 4th year, cereals; 5th year, onions or potatos.

Live Stock.—Six horses are kept for farm work; they are fed in summer on rye-grass, in the winter on beans, oats, chaff, carrots and mangolds.

Health.—The report of the health of the resident labourers and of the horses states that they are particularly healthy; free from ill-health and epidemic disease. The condition of the effluent water is not reported.

3.—GUISBOROUGH.

General Statement.—The peculiarity of this undertaking consists in the attempt to purify the sewage of a borough of 5 300 inhabitants on a small plot of 16 acres. The motive seems to have been a charitable wish of a landowner to aid the borough in its difficulties. The result of the experiment after eight years has been fairly but not perfectly successful, as the effluent water is not thoroughly purified; yet in later years the landowner has not suffered any direct loss from the farming operation.

Capital Account.—The expense per acre in preparing the land is very heavy. The capital is recovered by the annual profits and its interest by a permanent annual charge of 5 per cent. interest separately; the rent remaining fixed at the same rent that was charged before the sewage farm was established. The following table shows the gradual amortisation of the capital; the decrease in value of the crops is due to diminished demand for farm produce, on account of the depression of the iron trade in the district:—

	Value of Crop per acre.	Profit.	Loss.	Unredeemed Capital.
1870	—	—	—	£1 691·58
1871	£11·25	£2·38		1 689·20
1872	12·	—	47·17	1 736·37
1873	17·07	45·16	—	1 691·21
1874	24·30	163·04	—	1 528·17
1875	26·32	140·54	—	1 387·63
1876	19·95	50·31	—	1 337·32
1877	15·81	8·17	—	1 329·15
1878	16·25	10·84	—	1 318·31
		420·44	47·17	
Total in 1878		373·27		1 318·31

The valuation of stock in hand annually is included in the receipts for each crop. Though crops are not consumed on the land, a large portion of the produce is sold to the estate at a depreciation, an arrangement that precludes some of the real profits from the accounts.

The Sewage.—The sewage employed consists of the town refuse and simple sewage of 5 300 persons of Guisborough; also the surface drainage and road drainage, and the water used by the town and the waste of the tanyards. The Waterworks supply daily 11 228 cubic feet of water; besides, well water is used. The daily average supply of sewage is not mentioned. A special outfall-sewer of earthenware, 15 inches in diameter, branches off from the town sewer, 3 feet by 2 feet, above a small dam in it, and conveys the sewage to the head of the sewaged land. There are two storm overflows, one at each end of this outfall sewer, which discharge into a brook. The main sewage-carriers on the land are two 12-inch earthenware pipes, laid in banks; they bifurcate from the 15-inch pipe. The branch carriers are 6-inch pipes, placed at distances of 33 feet along the main carriers; but the distributing carriers are earth-cut trenches formed newly as the crop or the land may require. The soil is unfavourable to the filtration of sewage, and the effluent is impure. In winter five acres of fallow are employed to receive and filter the whole of the sewage, which flows alternately for a week on each plot of 2½ acres, during four months of the year.

Drainage.—The whole of the land is underdrained; the main drains are 8 inches by 6 inches in diameter; the branch drains vary from 4″ to 3″ in diameter, and are laid 5½ feet deep; the subsidiary drains are about 5 feet deep, and are laid 33 feet apart; the whole are puddled at the joints with clay. At one or two places where spring-water is met, the drains are 15 feet apart. The shrinkage of this underdrained clayey land causes minute fissures, through which unpurified sewage may find its way into the drains at some seasons of the year.

Crops.—Those of the year 1879 consisted of—Rye-grass 10·14 acres; Turnips, Mangolds and Carrots 5·60 acres; Rhubarb 0·31 acres.—(*See Irrigated Crops.*)

Health.—The report of the health of the resident labourers is favourable; there is no live stock on the farm; and no complaints have been made about the effluent, although it is discoloured and impure.

4.—WREXHAM.

General Statement.—The land is let on a lease of 19 years. It consists of 51 acres of pasture and 49·67 acres of arable land, the rest being occupied by roads and buildings.

Capital Account.—Before the present tenant hired the farm, £400 had been spent in preparing the land and making a sewage carrier; this amount is not included in the tabular statement, as it was virtually wasted. Settling tanks had been made at a cost of £700. The present tenant then expended £935 of capital, which is being recovered by annual payments out of profit. At present, in 1879, there remained £792 as capital charge after five annual payments. The accounts are given for the years 1876, 1877, 1878, each closing on 1st February of the year following.

The valuation of stock includes £670 for live stock, &c., sold to and held by the sub-tenant.

The Sewage.—The sewage of Wrexham flows into two settling tanks at the head of the farm; the liquid matter flows on to the farm in earth-cut carriers, earthenware pipes being used only in a few cases. All liquid matter in excess of 80 200 cubic feet daily, which is the wet weather supply, passes into a brook by storm overflows. The solid matters are removed from the tank, drained

thoroughly dried by an engine-driven fan, and sifted. It is then mostly made into artificial manure with bone dust and sulphate of ammonia, and sold, or is used direct on the land. About 300 tons of dry sludge is annually removed from the tanks.

Drainage.—About 4 acres are underdrained with 8-inch and 6-inch pipes, 6 feet deep and 120 feet apart. In wet places, isolated drains, constructed with 6-inch, 4-inch and 3-inch pipes, are laid $3\frac{1}{2}$ feet deep where required. Very little surface-effluent passes off the farm; the effluent from the underdrains is clear, and apparently very pure.

The Crops.—The rotation is Rye-grass for three years, fourth year Cereals, fifth year Mangolds. The acreage of crops for 1879 was:—

		Acres.
Pasture:—	Hay, grazing spring and autumn...	34
"	Grazing only	17
Arable:—	Italian Rye-grass	16·75
"	Black Tartarian Oats	11
"	Barley	6
"	Mangolds	6·81
"	Swedes and Potatos	3·60
"	Market Garden	5
		100·16

(*See Irrigated Crops.*)

Live Stock.—At the time of inspection there were 26 cows in milk, three dry, six calves and one bull on the farm. The dairy stock is tied up all the winter and part of the summer. In the summer the cows are fed night and morning on rye-grass, and graze in the meadow; in winter they are fed on hay, mangolds, cabbage, maize, meal and grains. The calves are invariably reared on skimmed milk and linseed. The average yield of milk is $1\frac{1}{2}$ gallons per cow per day; it is sold in Wrexham at 2*d.* per quart, though the usual retail price there is 3*d.* per quart.

Fourteen horses and ponies are kept on the farm, and in constant work at all seasons; but are fed on rye-grass from May to November, and on rye-grass, meadow hay, home-grown oats and maize in the winter. About ten pigs are kept; they are fed on skimmed milk, garden stuff, maize-meal and swill.

Health.—The resident labourers suffer from common catarrh

and coughs; one case of acute rheumatism. The children suffer from whooping-cough, mumps and measles; there are no other ailments. The cattle are generally healthy; there was a very mild outbreak of foot-and-mouth disease, and occasional cases of milk fever. The health of the horses is particularly good. The effluent water from the farm is pure and creates no nuisance, nor causes any ill-health or disease.

5.—BIRMINGHAM.

General Statement.—Apparently a greater extent of land would be desirable for operations of this special class. The peculiarity here consists in the farm being actually a sludge-farm conducted on masses of town refuse. The farm and sewage treatment are both under a manager appointed by a District Drainage Board, who hold 169·62 acres in freehold and 102 acres under lease. The farm is situated between the Tame and the Rea, and is liable to flooding.

Capital Account.—This includes £808 for embankment of the rivers; no rent is charged against the farm for the freehold land; yet no abatement is made for the 54 acres of farm land occupied in sludge-working. The rent chargeable for the whole is about its value to an ordinary farmer, as two adjoining farms are let at £2 and £3 5*s.* per acre.

The Sewage.—The whole volume of sewage from the population, 450 000 of the united district, is, in dry weather, about 1 924 800 cubic feet daily; three-fourths of this are heated chemically and passed into the watercourses of the district; only one-fourth of it, or 481 200 cubic feet daily, flows on to the farm land. At the gauge-dam, which is 4 feet wide, the gauging was 10½ inches deep on 4th June, and 10 inches on 11th August last year; these showing flow of sewage to be daily rates of nearly one million cubic feet, and 930 000 cubic feet. There are sewaged areas of three classes: one part, 30 acres, receives the simple sewage; a second, of 20 acres, receives unprecipitated sewage mixed with lime; the remainder of the farm receives effluent sewage after subsidence in tanks, all in earth-cut surface carriers.

As to the lime treatment: lime from Dudley is ground in water with a mill, and the slaked lime flows direct from the mill into

the sewer at a spot about a quarter of a mile from the outfall. In this way about 14 tons of lime are added daily to the sewage as it flows.

The subsidence treatment: there are three large settling tanks, 390 × 90 × 5½ feet, at the outfall, into which the sewage first flows; these are used alternately for a fortnight while the sludge is removed. There are also 16 small settling tanks, each receiving one-sixteenth of the sewage coming from the large tank employed. In these more sludge is deposited, and the effluent sewage is allowed to flow off from them on to the land.

The sludge is differently treated as semi-fluid sludge, which is pumped up and pushed on to the land in elevated wooden troughs by men with poles; and as heavy matter, consisting mostly of road-drift, which is removed with a steam-crane.

About 500 tons of moist sludge are raised daily, and 54 acres of land are required for receiving it in a year. The whole farm has already received one dressing, and a part of it two dressings of moist sludge. The land is prepared for its reception by raising small embankments, and then dividing it into a series of small tanks; after the sludge has consolidated in these, which takes a few weeks, it forms a deposit about a foot deep, and then it is dug into the land to a depth of two feet. The operations of preparing the land and digging in the sludge cost £12 per acre, chargeable to the farm when perfectly completed. The land is afterwards turned up with a steam plough every two years. The sludge appears not to amalgamate with the soil, and remains a mass of worthless fibrous matter on the ground for at least two years. The character of the soil, after the admixture, is altered, its absorbent properties being increased.

Samples of Sludge taken in August, 1879.

	Moist Sludge from Trough.	Consolidated Sludge.
Water	80·60	47·65
Dry matter	19·38	52.35
Total	100	100

Samples of Sludge taken in November, 1879.

	Sludge from Large Tank.	Sludge from Small Tank.	Consolidated Sludge.
Water	86·05	87·13	63.90
Dry matter	13·95	12·87	36·10
Total ...	100	100	100

Analysis of air-dried Sludge of 29th September, 1876, by Dr. Wallace, City Analyst of Glasgow.

	Sludge from large Settling Tank.	Sludge as dug into the land.
Water	12·70	13·16
Organic Matter	19·19	20·04
Phosphoric Acid	·40	·72
Sulphuric Acid	1·45	·35
Carbonic Acid	7·62	8·53
Lime	11·19	12·74
Magnesia	·90	1·37
Oxide of Iron	2·70	3·20
Alumina	2·68	2·58
Sand, &c.	41·13	37·93
	99·96	100·62
Phosphate of Lime	·87	1·57
Nitrogen	·52	·49
Equal to Ammonia	·63	·60
Calculated value per ton	10*s.* 9*d.*	11*s.* 5*d.*

Drainage.—About 197 acres of land is closely underdrained by drains 6 feet deep × 33 feet apart; in some places they are 66 feet apart. The effluent at the outfalls appeared like spring water.

The Crops.—No regular rotation of crops is observed, as much land is yearly sacrificed to sludge deposit. The crops most suitable are: 1st, Rye-grass; 2nd, Mangolds; 3rd, Cabbages while market gardening appears least so. The cropping for the year 1879 was thus:—

	Acres.		Acres.
Rye-grass	68	Potatos	10·5
Grass Land	26	Kohl-rabi	8·5
Wheat	9	Cabbage	12
Oats	15	Peas	4
Barley	26	Seeds	7
Mangold	25	Rhubarb	0·75
Turnips	13·28		
Swedes	7·5	Total	210·53(?)

Besides—

The land used for Sludge was...	17·5
„ occupied by works	18·68
„ „ Roads and Stream	25·90
(*See Irrigated Crops.*)	62·08

Live Stock.—There are 34 cows in milk, 10 feeding cows, 6 yearling heifers and 1 bull. The cows are kept in full milk about six months, and are fed in summer on dry stuff twice a day and on green food thrice a day; the food being rye-grass, cotton cake, and bean, oat, or maize meal. When feeding on grass, each cow receives 2lbs. of cotton cake and 4lbs. of meal. The dry and barren cows are fattened on cut hay, linseed cake and bean meal. In winter they are fed on brewer's grains and meal steamed. The average yield of milk in the milking season is 2¾ gallons per cow daily; this is sold at 9*d.* a gallon in summer and 9½*d.* in winter.

In February, 1879, there were 42 ewes, which produced 72 lambs in the year. They were pastured on rye-grass, and received cotton cake and kibbled maize; they were sold fat after a year's keeping. There were 45 pigs, which were fed on unsaleable vegetables steamed with sharps and pea-meal. There were 9 working horses, 4 colts and a foal.

Health.—The report states that the men employed are, as a rule, very healthy; but two men engaged on tank work died.

6.—Croydon.

General Statement.—The principal features in this sewage-farm are: 1st, that it is the oldest in England among those of modern times; 2nd, that it is worked at a farming loss on account of the immense rent, rates, tithes and taxes, though otherwise and under better control of the sewage, it might be made profitable; 3rd,] that an epidemic and diseases, formerly occurring in the neighbourhood, clearly traced to fouled sources of drinking supply contaminated by bad local drainage, distinct from that of the sewaged farm land, have given the sewage farm an undeserved bad reputation as regards health.

In 1857 the sewage of Croydon was applied to 15 acres of grass land. In 1860 the present farm was rented by the Croydon

Local Board, and 100 acres of it were irrigated out of 301 ; afterwards as much as 240 acres were irrigated at one time. In 1871 the farm was extended, there being then 55·75 acres freehold and nearly 400 acres of leasehold. A farming company then worked the farm for three years, and lost £7 072. In 1874 the Croydon Local Board appointed a manager to work the farm for them, and this arrangement still continues (1879).

Not more than 360 acres are irrigated at any one time; and as some crops are not irrigated continuously, 320 acres is the greatest extent irrigated throughout the year at one time.

Capital Account.—The total cost of works is comparatively small; and this would induce a belief that if sewage farming would pay a profit anywhere in England, it would be profitable here; but the causes above mentioned prevent it.

As to valuations of stock and plant: these were made only at the beginning and end of the financial years 1874 and 1878. For intermediate years they require interpolation by rate, as shown by the following table:—

INCOME.	£	EXPENDITURE.	£
Valuation 25 March, 1877 .	5 181	Valuation 25 March, 1874 .	4 732
Receipts.		Expenditure.	
Year ending 25 Mar., 1875 .	7 256	Year ending 25 Mar., 1875 .	10 636
” ” 1876 .	6 760	” ” 1876 .	9 578
” ” 1877 .	7 162	” ” 1877 .	9 390
Balance loss in 3 years ...	8 007		
	£34 336		£34 336

This shows an annual loss of £2 669 during those three years.

Although some of the recent loss is due to passing an excess of cold springwater on to the farm, thus ruining crops and spoiling the land; yet there is an evident steady annual loss, accounted for by the enormous rent, tithes, taxes and charges. For if such charges were reduced proportionately to those at Birmingham, Leamington, &c., a profit would be recorded. Actually the profit from farming exists, but is swallowed in rent.

The Sewage.—Though the soil of the farm and the disposition of the land is well adapted for irrigation, the sewage application suffers from want of storm outlets; for all the liquid con-

tents of the Croydon sewers have to be employed at all seasons. The amount of sewage was increased in 1878 by admitting subsoil water into the sewers; and amounted to about 1 233 000 cubic feet daily in addition to the local annual rainfall of 33 inches on the farm itself. The rainfall on Croydon itself is mostly conveyed into the natural watercourses and does not enter the sewers. The sewage is brought on to the Beddington farm in two outfall sewers by direct flow; one from Croydon proper, the other bringing the drainage from the southern side of the Norwood hills. Extractors are employed on the farm for the removal of solid matter from the sewage in accordance with Mr. Baldwin Latham's method. The liquid sewage is conveyed and distributed in earth-cut carriers.

Drainage.—The farm is not drained to any great extent, and is partly waterlogged, owing to the want of surface and subsoil drainage, and the enormous amount of subsoil water and sewage that it is compelled to receive. Notwithstanding this, the effluent water is at all seasons clear and limpid.

The Crops.—A great part of the farm consists of worn-out Rye-grass. The rotation followed is—for the first three years Rye-grass; 4th, Cabbage or vegetables; 5th, Mangolds; 6th, Cereals. The following were the crops in the year 1879.

	Acres.		Acres.
Italian Rye-grass	180	Brought forward ...	$415\frac{3}{4}$
Permanent Pastures	120	Vegetables...	$5\frac{1}{4}$
Mangolds	40	Rhubarb	4
Parsnips	1	Seedbeds	$\frac{3}{4}$
Cabbage	$3\frac{1}{2}$	Osiers	$1\frac{3}{4}$
Savoys	20		
Colewort	10		$427\frac{1}{2}$
Oats	$41\frac{1}{4}$	Waste	28
Carried forward ...	$415\frac{3}{4}$		$455\frac{1}{2}$

(*See Irrigated Crops.*)

Live Stock.—About 45 milk cows are kept; also 14 bullocks. The cows are fed in summer with rye-grass and cotton cake, and are turned out to grass; in winter they are stall fed with hay, pulped mangolds, distiller's wash, brewer's grains, cut straw, and cotton cake. The cows yield daily two to three gallons of milk,

which is sold at one shilling per gallon. The condition of the animals and their stabling admitted of improvement. Eighteen horses are kept on the farm. The farm is also a grazing lair for cattle and horses at a weekly charge; these greatly damage the herbage and spoil the ground, when moist.

Health.—Since 1874 there has not been any epidemic, and the health of the residents and neighbours has been good. There was one case of sickness of a man who attended the sewage extractors. The horses on this farm are very subject to grease. The effluent from the farm is pure and does not cause complaint.

7.—DONCASTER.

General Remarks. — This farm was leased to the present manager after being partly laid out by the Corporation of Doncaster.

Capital Account. — The Corporation expended £4 500 in preparing land and in buildings; the tenant completed these at a further expense of £650. The pumping station and main sewer together cost £18 000. As to valuation of Stock, the tenant invested £4 000 in working the farm, of this, £972 was paid as a valuation on entering, and £295 was afterwards expended in improvements, making the estimated valuation £1 267. The farming capital invested is thus not much more than that required for an ordinary farm. The ordinary rent of adjoining agricultural land is thirty shillings per acre, while the rent of this sewage farm is £3 per acre.

The Sewage.—The sewage of the town is collected at a low point in the town near the river Don, where it is raised 52 feet by pumps, at a yearly expense to the Corporation of about £350. The following were the quantities pumped in the years 1874 to 1878:—

	Cubic feet. Daily average.
1874	94 960
1875	87 397
1876	96 156
1877	87 476
1878	90 301
Average through five years... ...	91 258

At the pumping station there is a storm overflow into the river, which is occasionally used. The sewage is partially screened before pumping. At night it is stored in a tank sewer, holding 40 000 cubic feet; and the delivery on to the farm takes place only in the daytime. A 21-inch cast iron main, about two miles long, conveys the pumped sewage to a storage tank on the farm, which is now little used. The sewage on arrival is usually distributed direct in earthenware pipe-carriers, 18 inches to 9 inches in diameter, working under a small head; these are in earthen banks or below ground, and supply earth-cut carriers, which conduct the sewage to the land.

Drainage.—The soil is light and very porous, absorbing large quantities of sewage. About 90 acres of the farm are under-drained, the drains being placed at distances apart varying from 33 to 120 feet. Their depth in porous soil is 6 feet, in the loamy soil 4½ feet. There is no surface effluent, and at the time of inspection there was hardly any drained effluent.

A plot of 5 acres had been at one time prepared as a filter bed, being more closely drained; but as it was not wanted as such it was afterwards cropped like the rest of the farm. This farm forms an excellent example of careful, cleanly and economical working.

The Crops.—The sewage is applied to various crops in the spring and summer, also in the winter to a few crops, but more largely to fallow land. The following are the volumes and equivalent vertical depths of sewage applied to various crops in the year 1878:—

	Volume. Cubic feet per acre.	Vertical depth. Feet per acre.
Rye-grass	630 180	14·42
Permanent Grass	171 423	3·67
Mangolds	231 347	5·33
Beans	6 738	0·16

The rotation of cropping varies with the soil.

	1st.	2nd.	3rd.	4th.	5th.
On light land	Rye-grass (for 3 years)			Roots	Barley
On loamy soil	Roots	Wheat	Seeds	Wheat	—
On stiff soil	Wheat	Clover	Wheat	Beans	Fallow

The following are the crops of the year 1879 :—

	Acres.		Acres.
Rye-grass and Clover Seeds	75	Brought forward ...	272·5
Meadow	46	Peas...	4·5
Mangolds	31	Beans	5·5
Turnips and Swedes	34	Currants	1·5
Potatos	2	Gooseberries&Raspberries	1·5
Wheat	27	Osiers	3
Barley...	47·5		288·5
Oats	7·5		
Rye	2·5	Fallow	12
		Buildings &c....	4·5
Carried over ...	272·5		
			305·

(*See Irrigated Crops.*)

Live Stock.—There are 12 milk cows, 1 bull, and 31 heifers and steers (in 1879). The cows are kept in summer on the pastures, with a little rye-grass besides ; in the winter they are fed on roots and hay. Steers are fed on roots, cake and hay, and sold for beef. The cows yield about $1\frac{1}{3}$ gallons of milk per head per day. Owing to local objections to milk from sewage farms, very little is sold at 10*d.* per gallon. There is no local demand for rye-grass. The difficulties to profitable farming are thus very great. There are 150 breeding ewes, producing on an average 200 lambs ; they are all sold fat and fed on turnips, mangolds and seeds.

Fourteen pigs, including 2 sows, are kept and fed on skimmed milk, meat and vegetable waste.

Twenty-six horses and foals of different sorts are kept on the farm, and fed on sewaged rye-grass.

Health.—The health of the residents and labourers on the farm is generally good ; there has not been any epidemic, nor any death. The horses are free from grease and thrive well. The flock of sheep suffers slightly from foot rot. The cattle are healthy. The effluent drainage does not produce any nuisance or complaint.

8.—LEAMINGTON.

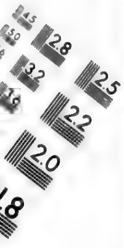
General Statement.—The details of the application of sewage to crops on this farm are given with completeness, so also the accounts; and as this is a particularly well-managed farm every detail of working and account is interesting in example and useful for future reference. These are therefore given in full. It happens to be a profitable farm, owing not only to good management, good quality of sewage, and suitable soil, but to local facilities for sale of produce of all sorts. Pumping the sewage to such a high lift seems the only disadvantage. The details of the irrigable land are these:—

	Acres.	Rent per acre.
Heathcote Farm—Grass Land ...	86·59	£2 4 0
" " Arable Land ...	284·37	
Park—Grass Land ...	345·70	£1 5 6
" Arable Land ...	47·56	
	764·22	
Lands of adjoining farmers irrigated in 1878	45	
	809·22	

Capital Account.—The details of capital expenditure to the sum of £31 071 are given in the general table. It further costs the Corporation of Leamington nearly £900 annually to lift the sewage; half of this, or £450, is repaid by the tenant as payment for sewage. The tenant incurred the expense of works necessary for conveying sewage to adjoining lands, and sells the sewage thus applied; he has also some privileges with regard to grazing in the park lands; apparently these arrangements in their entirety are considerably to his loss. But this does not affect the justly estimated profits of the sewage farm.

The details of the valuation of live and dead stock, mentioned at £8 299, are not given; probably the cost of converting the old farm buildings into improved and more suitable buildings is included in this.

The Sewage.—The farm receives the sewage of about 23 000 inhabitants of the Borough of Leamington Spa. This is collected at a site near the Leam in two receiving tanks, one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covered, having a capacity of about 80 000 cubic feet, the other open and of double that capacity; at this site there are also storm overflows into the river, and a pumping station. Here there is a pair of condensing beam engines, with 36-inch cylinders, and a stroke of 8 feet; each engine works a pair of single-acting pumps, 26 inches in diameter; the pair of engines when in full work make 11 to 12 strokes per minute; the indicated pressure on the rising main was 65 lbs. to the square inch during inspection. The engines are usually employed for 10 hours daily. There is telegraphic communication from the pumping station to the farm.

As far as possible all the sewage solids are pumped with the liquid; any solids that cannot pass, are removed by manual labour, and are disposed of by the Leamington Corporation.

The lift is 132 feet; the iron rising main is 20 inches in diameter for the first half mile, and 18 inches for the remaining $1\frac{3}{4}$ miles to the farm.

On the sewage farm are two tanks at the ends of the delivery pipes, one a small brick tank which intercepts a small amount of the solids. At the end of the branch delivery main there is a large open excavation for storing sewage, but this is now little used. After delivery, the sewage is in some cases conveyed in earthenware pipe carriers, but mostly in simple earth-cut trenches; the distribution is in earth-cut carriers. The quality of the sewage is good; and the whole of the farm is capable of being irrigated by it.

The quantity of sewage used annually, from 1st January in each year, is shown in detail in the following tables.

The results, tabulated in cubic feet per acre, are deduced from the tonnage of the original report, taking a ton at 35·883 foot-weights, or cubic feet at the density of water: as the actual density of the liquid sewage is not mentioned.

During the Year 1872. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth in feet.	Average depth of a watering.
Italian Rye-grass ...	64	23	10·46	317 117	7·28	0·317
" "	25	26	10·36	363 272	8·34	0·322
Cabbage	20, 21	6	6·41	101 222	2·32	0·387
Market-garden	22	2	7·79	(?)263 742	(?)6·05	0·303
Mangold	44	9	6·86	115 705	2·66	0·295
Italian Rye-grass......	65	27	10·82	369 393	8·48	0·314
Fallow for Beans......	54	1	9·43	73 182	1·68	1·684
Permanent Pasture...	67	5	6·85	65 559	1·51	0·303
Italian Rye-grass......	27, 28	23	17·36	322 927	7·41	0·322
Permanent Pasture	50, 41, 45, 63, 46	3	41·00	44 124	1·01	0·337
Fallow for Wheat ...	58, 59	2	20·10	32 521	0·75	0·373
Seeds	66	7	10·65	99 466	2·28	0·361
Mangold	51, 53	9	18·34	129 877	2·98	0·331
Rye-grass after Wheat	48	4	11·23	66 768	1·53	0·376
Fallow	13, 71	4	20·39	58 430	1·34	0·335
Seeds	47	11	10·20	158 642	3·64	0·331
For Grass	43	4	9·03	64 185	1·47	0·368
			223·68			

Total Sewage in 1872.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 223·68 acres	30 163 900 ...	134 850 ...	3·10
Supplied to farmers ...	3 134 100 ...	— ...	—
Total pumped in 1872 ...	33 298 000 ...	— ...	—

During the Year 1873. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth in feet.	Average depth of a watering.
Cabbage	24	4	5·33	59 628	1·37	0·342
Seeds..................	44, 47	7	17·06	107 561	2·47	0·352
Permanent Pasture	41, 45, 46, 67, 26	1	29·44	27 090	0·62	0·622
Italian Rye-grass ...	42	16	8·75	214 820	4·93	0·308
Mangold	58, 59	3	20·09	51 403	1·18	0·393
Market-garden	13	7	12·66	101 293	2·33	0·335
It. Rye-grass part of	27, 28	24	13·00	349 170	8·02	0·334
Savoys ......part of	27, 28	23	0·76	4 430 170	10·17	0·442
Italian Rye-grass ...	48	30	11·23	514 866	11·82	0·394
Fallow	69	1	9·52	13 023	0·30	0·299
Italian Rye-grass ...	25	38	10·36	527 560	12·11	0·319
" " ...	54	8	9·43	115 702	2·66	0·332
" " ...	43	35	9·03	487 200	11·18	0·320
Fallow	13	4	12·66	66 600	1·53	0·382
Stubble	65	7	10·82	92 480	2·12	0·307
Cabbage	22	1	7·79	11 396	0·26	0·262
			187·93			

Total Sewage in 1873.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 187·93 acres	33 990 000 ...	180 863 ...	4·15
Supplied to farmers ...	12 351 000 ...	— ...	—
Total pumped in 1873...	46'341 000 ...	— ...	—

During the Year 1874. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth in feet.	Average depth of a watering.
Cabbage...............	27, 28	3	13·76	40 791	0·94	0·312
Fallow	64	4	10·46	61 087	1·40	0·351
Italian Rye-grass, pt	21, 22	5	14·08	84 353	1·94	0·387
Barley fallow	24	1	5·33	26 693	0·61	0·613
Cabbage fallow	27, 28	7	13·76	96 611	2·22	0·317
Seeds ......20 & part of	21	22	6·00	324 507	7·45	0·338
Italian Rye-grass, pt. of	43	27	9·02	250 652	5·75	0·213
" "	25	29	10·35	409 980	9·41	0·324
Mangold	65, 66	7	21·48	106 128	2·44	0·348
" part of	43	33	9·02	483 287	11·89	0·360
Italian Rye-grass ...	54	33	9·43	453 187	10·40	0·315
Parsnips & Carrots .	64	1	10·46	16 676	0·38	0·382
Perm. Pasture... 41, 45	46	2	19·36	41 410	0·95	0·475
Italian Rye-grass ...	48	23	11·23	329 383	7·56	0·329
" " ...	13	22	12·54	309 630	7·11	0·323
Turnips	20, 21, 22	1	4·00	50 101	1·15	1·150
Second crop of Cabbage	27 28	7	13·76	99 850	2·29	0·327
Rye-grass after Cabbage	27, 28	5	13·76	64 921	1·49	0·298
Italian Rye-grass ...	42	21	8·75	275 982	6·34	0·302
" " ...	47	4	10·20	50 123	1·15	0·288
Second crop of Cabbage	25	3	10·35	42 623	0·98	0·326
Italian Rye-grass ...	24	9	5·33	127 200	2·92	0·373
Permanent Pasture	67	2	10·00	6 614	0·15	0·075
Stubble	58, 59	1	20·09	24 608	0·56	0·565
			272·55			

Total Sewage in 1874.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 272·55 acres ...	39 329 000 ...	144 300 ...	3·31
Supplied to farmers ...	7 734 100 ...	— ...	—
Total pumped in 1874 ...	47 063 100 ...	— ...	—

During the Year 1875. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth in feet.	Average depth of a watering.
Italian Rye-grass, part of	13	18	8·54	245 022	5·62	0·312
Cabbage ...... part of	13	17	4·00	288 733	6·63	0·390
Italian Rye-grass,	20, 21, 22	35	14·19	458 520	10·53	0·301
" "	24	49	5·33	987 450	22·67	0·462
Cabbage	25	14	10·36	121 622	2·79	0·189
Italian Rye-grass ...	27, 28	42	13·76	988 380	22·69	0·545
Mangold	49, 55 & 56	4	5·00	52 763	1·21	0·303
Italian Rye-grass ...	47	36	10·20	585 636	13·44	0·373
" "	54	25	9·43	375 707	8·63	0·345
Cabbage, Strawberries, & Rhubarb	64	4	8·47	67 417	1·55	0·387
Fallow for Mangold	65	2	10·82	30 431	0·70	0·349
Seeds	72	3	9·47	52 616	1·21	0·403
Permanent Pasture,	41, 45, 46, 50, 67	7	37·11	64 432	1·48	0·211
Fallow for Mangold	42, 43	23	14·02	34 684	7·96	0·346
			160·70			

Total Sewage in 1875.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 160·70 acres	44 721 000	278 290	6·39
Supplied to farmers ...	7 378 600	—	—
Total pumped in 1875 ...	52 099 600	—	—

During the Year 1876. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth in feet.	Average depth of a watering.
Italian Rye-grass......	23	31	10·37	439 687	10·09	0·326
" "	42	47	6·85	597 463	13·72	0·292
" "	27, 28	47	13·76	643 775	14·78	0·314
" "	24	56	5·33	758 165	17·41	0·311
" "	22	21	7·79	277 447	6·37	0·303
Seeds	61	22	12·27	310 580	7·13	0·324
Fallow	60	20	10·36	36 122	0·83	0·041
"	20, 21	6	6·43	99 652	2·29	0·381
"	part of 13	3	4·00	54 444	1·25	0·416
"	42, 43	2	17·77	24 510	0·56	0·281
Cabbage	25	7	10·36	101 867	2·34	0·334
Perm. Pasture	41, 45, 46, 67	8	26·21	107 299	2·46	0·308
" " ...	30, 41	17	12·11	249 983	5·74	0·337
Mangold, Strawberry and Rhubarb	64	14	10·46	193 211	4·44	0·317
Bean Fallow	54	3	9·43	44 639	1·02	0·341
Mangold	20, 21	11	6·41	184 186	4·23	0·384
Italian Rye-grass, part of	13	6	8·54	86 258	1·98	0·330
Rye-grass after Wheat	48	7	11·21	102 759	2·36	0·337
Grass Fallow	22	9	7·79	124 726	2·86	0·318
			197·45			

Total Sewage in 1876.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 197·45 acres	42 569 700...	215 593 ...	4·95
Supplied to farmers	10 552 200...	— ...	—
Total pumped in 1876...	53 121 900...	— ...	—

During the Year 1877. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet.	Equivalent depth feet.	Average depth of a watering.
Italian Rye-grass (7 acres) and Permanent Pasture (26 acres), together in	41, 45, 46, 67, 44	29	33·00	395 417	9·08	0·313
Italian Rye-grass ...	42	26	8·00	383 357	8·80	0·338
„ „	23	27	8·50	396 737	9·11	0·337
„ „	13	36	4·00	524 880	12·05	0·334
„ „ 22, and part of	21	14	8·00	206 050	4·73	0·338
Ital. Rye-grass, Strawberries & Rhubarb	64	18	10·46	247 434	5·68	0·316
Fallow for Oats, 20, and part of	21	20	7·00	288 340	6·62	0·331
Mangold	24	15	5·08	218 358	5·01	0·334
Cabbage .... part of	43	5	4·25	137 901	3·17	? 0·633
„ ......part of	27&28	4	5·50	61 856	1·42	0·355
Mangold ...24, pt. of	27&28	13	14·34	224 127	5·15	0·396
„	29	23	7·00	300 722	6·90	0·300
Turnips ...... part of	27&28	2	3·00	37 474	0·86	0·430
Italian Rye-grass ...	48	32	11·23	458 970	10·54	0·329
Savoys ....part of	48	2	2·00	38 987	0·90	0·448
Fallow for Turnips	58, 59	5	20·00	75 354	1·73	0·346
Italian Rye-grass ...	65	5	10·00	37 677	0·86	0·173
„ „	25	2	10·36	39 028	0·90	0·448
Parsnips and Cabbage part of	43	10	5·02	321 663	7·38	0·738
Permanent Pasture	50	4	10·90	57 610	1·32	0·331
Fallow for Turnips	54	4	9·43	66 590	1·53	0·382
			197·07			

Total Sewage in 1877.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 197·07 acres...	47 158 000...	239 297 ...	5·49
Supplied to farmers	6 817 800...	— ...	—
Total pumped in 1877 ...	53 975 800...	— ...	—

During the Year 1878. Crop.	No. of Field.	Number of waterings.	Acres.	Volume of sewage per acre in cubic feet	Equivalent depth in feet.	Average depth of a watering.
Italian Rye-grass......	22	6	6·56	84 501	1·94	0·323
" "	23	29	10·37	407 413	9·35	0·323
" "	25	31	10·36	429 703	9·86	0·318
Mangold	27, 28	21	13·76	296 580	6·81	0·324
Italian Rye-grass......	42	11	8·75	148 115	3·40	0·309
" "	48	21	11·22	301 305	6·92	0·329
Cabbage	44	17	6·86	215 785	4·95	0·291
Italian Rye-grass......	65	20	10·82	266 046	6·11	0·305
Cabbage and Italian Rye-grass	13	11	12·66	162 840	3·74	0·340
Oat Fallow	24	9	3·33	122 380	2·81	0·312
Potatos & Savoys ...	20, 21	6	6·41	82 212	1·89	0·314
Perm. Pasture	41, 45, 46, 67	7	26·21	101 243	2·32	0·332
Mangold	54	21	9·43	296 040	6·80	0·324
Fallow	51, 53	2	19·00	39 745	0·91	0·456
Italian Rye-grass......	24	7	5·33	105 643	2·43	0·346
			161·07			

Total Sewage in 1878.	Cubic feet.	Cubic feet per acre.	Equivalent depth in feet over the whole.
On 161·07 acres	32 098 200 ...	199 281 ...	4·575
Supplied to farmers... ...	18 703 500 ...	— ...	—
Total pumped in 1878 ...	50 801 700 ...	— ...	—

Drainage.—The land is mostly drained, the stiff land at a depth of 4 feet with drains 40 feet apart, and the light land at 5 feet deep with drains 60 feet apart. There is no surface effluent, and the drainage effluent is comparatively small in amount.

The Crops.—These are given in detail in the Sewage Tables for the years 1872 to 1878 inclusive, with the amount of sewage applied to each crop. These volumes vary: probably in accordance with the soil as well as with the crop; hence also the following abstracts are given for the same fields, which can be conveniently compared.

ABSTRACT OF YEARLY SUPPLY OF LIQUID SEWAGE TO VARIOUS CROPS ON THE SAME FIELD.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
Field No. 13: 12·66 acres.			
1872	Fallow	4	1·34
1873	Market Garden	7	2·33
1874	Rye-grass	22	7·11
1875	Rye-grass	18	5·62
	Cabbage	17	6·63
1876	Rye-grass	6	1·98
	Fallow	3	1·25
1877	Rye-grass	36	12·05
1878	Rye-grass ... } Cabbage ...... }	11	3·74
Field No. 22: 7·79 acres.			
1872	Market Garden .	2	6·05
1873	Cabbage	1	0·26
1874	Rye-grass	5	1·94
1875	"	35	10·53
1876	Grass Fallow ...	9	2·86
1877	Rye-grass	14	4·73
1878	"	6	1·94
Field No. 24: 5·33 acres.			
1873	Cabbage	4	1·37
1874	Barley Fallow ...	1	0·61
1875	Rye-grass	49	22·67
1876	"	56	17·41
1877	Mangold	15	5·01
1878	Oat Fallow	9	2·81
	Rye-grass	7	2.43

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
Field No. 25: 10·36 acres.			
1872	Rye-grass	26	8·34
1873	"	38	12·11
1874	"	29	9·41
"	2nd Crop, Cabbage	3	0·98
1875	Cabbage	14	2·79
1876	"	7	2·34
1877	Rye-grass	2	0·90
1878	"	31	9·86
Fields Nos. 27 and 28; 13·76 acres.			
1872	Rye-grass	23	7·41
1873	"	24	8·09
1874	Cabbage Fallow.	7	2·22
1875	Rye-grass	42	22·62
1876	"	47	14·78
1877	Mixed Crops, various		
1878	Mangold	21	6·81
Fields Nos. 41, 45 and 46: 19·36 acres.			
1872	Perm. Pasture ...	3	1·01
1873	" " ...	1	0·62
1874	" " ...	2	0·95
1875	" " ...	7	1.48
1876	" " ...	8	2·46
1877	" " ...	29	9·08
1878	" " ...	7	2·32

ABSTRACT OF YEARLY SUPPLY OF LIQUID SEWAGE—*continued.*

Field No. 67 : 6·85 acres.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
1873 to 1878.	Permanent Pasture with watering similar to fields 41, 45 & 46.		

Field No. 48 : 11·23 acres.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
1872	Rye-grass after Wheat	4	1·53
1873	Rye-grass.........	30	11·82
1874	„	23	7·56
1875	Wheat	0	––
1876	Rye-grass after Wheat	7	2·36
1877	„	32	10·54
1878	„	21	6·92

Field No. 54 : 9·43 acres.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
1872	Bean Fallow ...	1	1·68
1873	Rye-grass	8	2·66
1874	„	33	10·40
1875	„	25	8·63
1876	Bean Fallow ...	3	1·02
1877	Turnip Fallow	4	1·53
1878	Mangold	21	6·80

Field No. 64 : 10·46 acres.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
1872	Rye-grass	23	7·28
1873	Not Irrigated...	—	—
1874	Parsnips and Carrots ...	1	0·38
	Fallow	4	1·40
1875	Cabbage, Strawberries, and Rhubarb......	4	1·55
1876	Mangold, Strawberries, and Rhubarb......	4	4·44
1877	Rye-grass, Strawberries, and Rhubarb......	18	5·68

Field No. 65 : 10·82 acres.

In	Crops.	Number of Waterings.	Total depth of Liquid. Feet.
1872	Rye-grass	27	8·48
1873	Stubble	7	2·12
1874	Mangold	7	2·44
1875	Mangold Fallow	2	0·70
1876	(None) ...	—	—
1877	Rye-grass	5	0·86
1878	Rye-grass	20	6·11

The cropping for 1879 was as follows :—

	Acres.		Acres.
Italian Rye-grass	49·23	Potatos	4·
Pasture	86·59	Oats	18·03
Seeds	16·64	Barley	18·50
Mangolds	23·96	Wheat	68·72
Carrots	2·75	Cabbage	6·
Parsnips	6·85	Beans	45·56
Turnips	23·90	Rhubarb	0·50

(*See Irrigated Crops.*)

Live Stock.—Cattle, sheep, horses and pigs.

Health.—The health of the residents and persons in the neighbourhood has been exceptionally good; there has not been any complaint of nuisance or effluvia, nor any fever or illness attributable to the farm or its produce. The horses are not subject to grease; the cattle and sheep are healthy. The drained effluent is small and unobjectionable.

Accounts.—The following is an abstract from the accounts of Leamington Sewage Farm for the three years 1876, 1877, 1878:—

INCOME FROM 1ST JANUARY IN EACH YEAR.

	1876.	1877.	1878.
	£	£	£
Valuation at end of Year	8 157	8 366	8 299
Received for irrigating adjoining land ...	60	49	40
Improvements charged to Capital	100	75	213
Sale of Wheat	489	902	801
„ Barley	—	101	132
„ Oats	[illegible]0	45	26
„ Mangolds	[illegible]1	90	61
„ Turnips	38	—	—
„ Carrots and Parsnips	50	—	—
„ Potatos	85	—	300
„ Cabbage	84	225	
„ Beans	25	18	11
„ Rhubarb	10	10	—
„ Grass	814	484	426
„ Hay and Straw	665	512	384
Provender for estate horses, game, &c. ...	808	753	626
„ „ carriage horses	316	371	261
Sale of Cattle	1 927	2 084	2 186
„ Sheep	522	648	673
„ Pigs	93	64	67
„ Horses	371	118	34
„ Milk	1 177	1 352	1 541
„ Wool...	127	147	173
Grass keep	161	67	43
Horse hire	108	146	177
Use of horses, steam-engine, &c.	174	38	—
Miscellaneous...	12	48	3
	16 494	16 713	16 477

EXPENDITURE FROM 1ST JANUARY IN EACH YEAR.

	1876.	1877.	1878.
	£	£	£
Valuation at beginning of Year	7 684	8 157	8 306
Rent	1 309	1 430	1 430
Rates, Taxes and Insurance...	227	158	190
Veterinary, Blacksmith and Harness ...	146	110	126
Implements purchased and repaired ...	92	102	168
Provender	1 121	1 432	976
Artificial Manure	92	158	82
Management, Wages and Beer	1 988	2 048	2 035
Live Stock—			
Cattle	1 415	1 375	1 458
Sheep	86	103	50
Pigs	—	3	—
Horses	156	111	30
Seed—			
Wheat	69	57	66
Barley	15	22	21
Oats	41	21	30
Mangold	24	—	—
Potatos	96	60	40
Beans	48	—	—
Grass	123	126	123
Railway Bills	9	10	8
Coal	51	39	47
Drain pipes, Ashes, &c.	58	17	6
Steam Cultivation	9	—	34
Repairs to Buildings, Roads, &c., and Paint	8	2	2
New Buildings	—	—	181
General Expenses	30	26	23
Miscellaneous...	69	129	117
Wages paid for Agricultural Society... ...	36	—	—
Leamington Corporation, for Sewage ...	450	450	450
Balance, Profit	1 042	567	478
	16 494	16 713	16 477

9.—READING.

General Statement.—The farm-land consists of 688 acres out of 770 purchased by the Corporation of Reading for £80 300 inclusive of all compensation. It consists of 350 acres of pasture, 325 arable, and 13 let in allotments. At the time of inspection 76·06 acres were ready for irrigation, and 54 acres more were under preparation for it. The drainage of Reading is from 40 000 persons; but of this amount only that from 33 000 persons is conveyed to the farm. The soil is porous, and well suited to the object, but the land is liable to be flooded to the extent of 350 acres.

Capital Account.—Apart from the sum of £80 300 expended in farm land and compensation, the site of the pumping station cost £804; the rest of the details are given in the tabular statement, the whole amounting to £14 948, in which is included the sum of £5 091 spent on farm buildings, farm engines and cottages.

The Sewage.—This is collected and screened at a pumping station in the town, on the banks of the Kennett, where is also a storm water overflow. The waterpower of the river drives two turbines out of three, which work four single-acting force-pumps, 18 inches diameter, of maximum stroke 30 inches.

Steam-power is used when the river is in flood. There is a pair of horizontal high-pressure condensing engines, each having a cylinder 24 inches in diameter, and 42 inches stroke; these drive a pair of plunger pumps 30 inches in diameter, of 36 inches stroke.

The sewage is pumped during 11 hours in the daytime to a lift of 43 feet; at night it accumulates in two receiving tanks and in the outfall sewer. The pumping of the sewage, which varies between 80 000 and 128 000 cubic feet daily, in addition to the cleansing and flushing of the sewers, costs, on an average of two years, £731 annually.

The sewage is conveyed from the pumping station to the farm, a distance of 2·43 miles, partly in a 24-inch cast-iron main, 1·55 miles long, which discharges into a 36-inch brick culvert 0·86 miles long; on arrival at the farm the sewage is conveyed in earthenware pipes as main carriers below the surface, and distributed on the surface of the land in earth-cut carriers.

Drainage.—The sewaged land is under-drained in some parts 4 feet deep, with drains 30 feet apart, in others 15 feet apart; but over the greater part they are 60 feet apart. An area set apart for filtration was completely waterlogged.

The Crops.—The following table gives the cropping for the year 1879:—

	Acres.
Rye-grass	51·
Mangolds (irrigated)	31·75
" (not irrigated)...	7·
Wheat	31·5
Oats	96·
Cabbages (irrigated)	8·
Beans	38·
	263·25
Land under preparation for Sewage	140·
Grass-land	271·75
Let in allotments	13·
	688·

(For account of the condition of the crops, *see Irrigated Crops.*)

Live Stock.—There were 257 head of cattle on the farm, of which 81 were cows in milk. The cows are fed in summer on rye-grass, also receiving some fine pollards, and in winter on cut hay, mangolds, fine and coarse pollards, and occasionally some crushed oats. These yield, on an average, two gallons of milk per head daily throughout the year. The milk sells in Reading at 10*d.* per gallon, and in London at 20*d.*, 18*d.*, and 16*d.* per barn gallon.

There are 19 horses, mostly of French breed, kept on the farm, for farmwork and cartage.

Health.—Measles and whooping-cough, also then prevalent in Reading, appeared on the farm in winter and spring. The residents are otherwise healthy; the sewage irrigation appears not to be prejudicial to health in any way. The cattle are healthy.

English Sewage Irrigation.

Conclusions.—From the preceding accounts and statistics, as well as from professional experience and personal observation, certain conclusions are inevitable.

1. That fæcal matter is most advantageously and economically disposed in application to farm land.

2. That an excess of waste water, especially cold spring water, causes ruin to farm crops, and spoils the land itself.

3. That town refuse, as precipitated sludge, is comparatively useless on farm land; and can only be utilised in any way under specially favourable conditions.

4. That road-grit can be advantageously employed on farms, merely when the farm soil is such as requires any such mixture.

5. That factory refuse may be applicable only under certain conditions; so also mineral refuse.

Hence the need of separation and subsidence, whenever useless matter enters largely into the composition of the refuse of a town. It cannot be reasonably expected that a sewage farm must purify town refuse of all sorts under all conditions, as asserted by Dr. Frankland. A farm can, however, almost always utilise moist effluent or flowing sewage after subsidence of the very heavy solids, provided the liquid is not in excess of requirements. As for the rest, much is utterly valueless, and should then be burnt or carbonised—a very economic process of disposal; while any utilising process may be adopted for the extraction and employment of useful matter of any sort in the residue.

Granting that a sewage farm shall only receive the sewage it requires, it will, under good management, yield a well-purified effluent water for discharge into the natural water-courses; and, in this respect, afford greater economy than any other method. As for the farming profits, they will depend on the rent, tithes taxes, &c., being fair, and the farm management being skilful; thus corresponding to farming of other sorts.

It is, however, absurd to expect any such farm to pay for the sewage or for the lifting it to any height; or for any special flood-preventive works; as the capital expended in preparing the land for irrigation, and in drainage works, is necessarily high. On

the contrary, a town should pay the farmer for the purification he effects; if any payment is to be made.

Apart from *strict* sewage irrigation of farm land, there are two special processes requiring notice, as they consist in sewage irrigation pressed to the two extremes. One is sludge-farming, the other is filtering sewage on small plots of land.

The former has been profitably carried out at Birmingham for several years under very careful management; it seems, however, a disgusting method, as well as a needless one; and it is not yet known how long it can be continued without eventually spoiling the land for all purposes.

The latter has been well effected in certain favourable cases, such as at Merthyr Tydvil, where a patch of gravelly soil happened to be very conveniently situated for the purpose; but it is not a mode generally applicable.

In both of these cases the matter, both inert and fertilising, is continually applied to a soil, but most of it is allowed to remain there unutilised, as the crops, if any, cannot assimilate so large an amount. The corresponding case occurs in flooded lands, where the crops are ruined from the excess of moisture that they cannot imbibe.

As to filtration, we are all aware that there are limits to the purifying power of any filter used for a long time, whether small or large; and that a filter consisting of some acres of land cannot be easily cleansed so as to entirely renew its functions. Such an expedient cannot be lasting; although periods of intermittent action greatly defer the inevitable future cessation of efficiency.

As also chemical processes for obtaining a pure effluent are costly and inefficient, farming with effluent and suitable sewage remains the only sure and economic method. The principle has been, under certain limits, adopted in India and China for ages past; as well as in Northumbria for a very long time; although on a large scale it is still comparatively a novelty in Europe.

IRRIGATED CROPS.

The following short accounts of crops, irrigated with sewage, have been condensed from those given in the report of judges appointed by the Royal Agricultural Society of England to adjudicate prizes in the sewage farm competition of 1879 and 1880. Those judges were Messrs. Latham, Read, and Thursfield; of whom the two latter were agricultural experts.

To those unacquainted with English agricultural technicalities, many of the expressions used, such as "clean," "middling," and "fair," may appear very vague; but in their special applications these have distinct technical meanings, conveying definite impressions to those trained to them.

The division of the sewage farms into two classes—

I. Small farms less than 200 acres,

II. Large farms from 200 to 800 acres,

is followed here, in the same order as in the section treating of their irrigation, where the rotation of crops is given for each case

Small.	Sludge Farm.	Large Farms.
1. Aldershot	5. Birmingham	6. Croydon
2. Bedford		7. Doncaster
3. Guisborough		8. Leamington
4. Wrexham		9. Reading

The order of the crops is generally thus:—1st, Forage; 2nd, Roots; 3rd, Cereals; 4th, Market Garden and special crops.

SMALL FARMS.

1. ALDERSHOT.

The crops grown are Rye grass, Potatos, and Rhubarb.

Rye-grass.—This crop stands from one to two years, and is cut four, five, or six times a year. Two to three bushels to the acre of home-grown seed are sown in September or October, following potatos, after grubbing and cleaning the soil. The Rye-grass is sold to cowkeepers and forage contractors; it is generally sold on the land, but is sometimes made into hay; in the spring it is sold by the acre The second crop of the year

is selected for seed growing: from four to six quarters of seed are obtained per acre, and at the same time one-and-a-half to two tons per acre of rye-grass hay are made. The land is then ploughed for a following potato crop.

Potatos.—The special variety, chosen by Mr. Blackburn as most suitable, is imported direct from America: they grow with little haulm, and do not suffer from disease. But several sorts, early and late, are grown so as to keep the sale in constant succession. In preparing the land, a skim-coulter attached to the plough is used to turn the Rye-grass completely over. The land is dressed with 3 to 4 cwt. of superphosphate of lime per acre. About 12 cwt. of seed potatos are planted in an acre. They are planted on ridges which are 26 inches apart, at distances of 12 inches; they are not irrigated during growth, but depend on previous irrigation and manure ploughed into the soil. The crop is usually sold on the ground.

Rhubarb.—This crop is grown for three years, when the selected roots are re-divided. After deep trenching and manuring, the young plants are placed at distances of three feet. They receive liquid sewage during growth: in winter they are protected with stable litter. The crop is sold for market up to 1st June, after then it is sold for wine manufacture. Pulling ceases in August.

2. Bedford.

A large variety of crops are grown:—Rye-grass, Roots, Cereals, and Market Garden.

Rye-grass.—This crop stands for two years, and is sown, either in the autumn or the spring as preferred. The district being always well provided with green food, the sale of this produce is at very low prices. The absence of live stock on this farm for consuming the produce is a serious defect in the arrangement, which will soon be remedied.

Potatos.—The land is well manured before this crop, which is not irrigated during the growth. The sorts preferred are the early Ashleaf and the Magnum Bonum. They are planted on the flat, at distances of 15 to 18 inches apart according to the variety, the rows being 18 to 30 inches apart. The crops were splendid, and free from all disease—seven acres yielding 30 tons.

Mangolds.—These also are planted on the flat (this usual mode at Bedford, being preferred there for even distribution of sewage); they are drilled in rows 26 inches apart, and are hoed out to 12 inches between plants. Five pounds of seed are sown per acre. They are irrigated during growth: one field sewaged in the winter was capital. The early-sown Mangolds, both here and on other farms, have run to seed.

Swedes.—A small quantity has been grown but not sewaged. Three pounds of seed per acre is drilled in rows 24 inches apart, the roots are then hoed out to 12 inches between plants.

Carrots.—These are not sewaged during growth. They are drilled in rows 12 inches apart, the plants are at distances of 4 to 6 inches. The crop sold for £16 10*s.* per acre, though it did not appear a very good one.

Parsnips.—These were a very fine crop. Seven pounds of seed per acre is drilled; the rows are 12 inches apart, the plants 8 to 10 inches apart.

Onions.—Sewage is applied to the land before sowing, but not to the crop during growth. Eight to ten pounds of seed per acre is sown, according to the land and time of sowing. The rows are 8 inches apart, the drills 4 to 6 inches. The cost of cleaning this crop is about £5 10*s.* per acre. The Onions are thinned out during the second cleaning. The crop was very fair for the season, excepting in places where water lodged.

Wheat.—This crop had followed Potatos. Red Browick is the variety grown. It was level, heavy and good. It had not been sewaged during growth.

Oats.—These were sown on land in which Parsnips and Mangolds had grown the year before. White Polish were the sort grown, they were not sewaged during growth; but were a very good and heavy crop, better on the land following the sewaged Mangolds than on that following the unsewaged Parsnips.

Barley.—This crop followed Mangolds on land sewaged after removal. It was a heavy crop.

Market Garden Crops.—The Rhubarb was grown on land that was seldom sewaged. The Cabbages were a good crop, considering the severe winter. Cauliflowers answer well on this farm. Lettuces and Asparagus were grown on land that occa-

sionally receives sewage. The two following require special notice.

Celery.—This is found one of the best of the sewaged crops grown. The trenches are well sewaged before planting; during growth the sewage is applied between the rows, and the plants benefit greatly from frequent dressings.

Prickly Comfrey.—This is grown for horse fodder. The roots were planted in March, set 24 inches apart each way, and three cuttings were taken in that year. The crop had been continuously flooded with sewage for three weeks in succession, and had benefited from it. It seemed impossible to damage this plant with sewage irrigation.

3. GUISBROUGH.

The crops consisted of Rye-grass and Common Grass, Roots and Rhubarb.

Rye-grass.—This crop stands for two years, and gives four cuttings yearly. Generally one half of it is ploughed up every year to be followed by roots. Three bushels of seed are sown per acre, and it is not sewaged always in the winter. In 1875 the first year's grass realised £19 per acre, the second years' grass £33 per acre; the whole averaging £26 per acre; in 1876 the average was £17 10*s.*; in 1878 £15 15*s.* per acre.

The other grass land is used for purifying sewage in irrigation, wh en not required for crops.

Mangolds.—The crops here grown on sewaged areas and irrigated during growth are vastly superior to the ordinary farm Mangolds of the neighbourhood. The seed is drilled in rows on the flat 2 feet apart, the plants 1 foot apart. The crop of 1878 was drilled on the 13th of May, and did not run to seed, as in many other places on sewage farms. The crop realised £23 10s. per acre.

Swedes.—This crop receives very little sewage during growth. The crop of 1878 ran to seed, and only realised £11 per acre.

Carrots.—The crop of 1878 was sown very late, on the 12th of May. Eight pounds of seed per acre are drilled. The rows on the flat are 18 inches apart, the plants 4 inches apart. The crop realised £20 per acre.

Rhubarb.—This crop is sewaged. The roots are planted 4 feet apart. The right of pulling the crop is sold at the rate of 4*d.* per root for the season. This crop realised at about £48 per acre; but in more prosperous times, as in 1875, it has been sold at £132.

4. Wrexham

The crops are Rye-grass, Permanent Grass, Roots, Cereals and Market Garden crops.

Rye-grass.—This crop here stands for three years, giving four cuttings the first year, six or seven cuttings the second year, and four or five the third year; the average of the whole grown in three years weighs about 40 tons annually per acre. The seed is usually sown about the 1st of April, at the rate of two bushels per acre, and the first cutting from it is taken in July. It is copiously irrigated with sewage after every cutting of grass. It generally realises 9*d.* per cwt. Unsuccessful attempts have been made with a Gibbs' Drying Cylinder to make good hay from it.

Permanent Grass.—This grass land received very copious supplies of sewage through the winter, but was not damaged by the excessive amount; after having been grazed until 27th May it gave a very good hay crop, and was grazed again in the autumn. The meadow reserved specially for grazing is only occasionally irrigated.

Potatos.—Sewage and manure are applied to the land; but sewage is not used during the growth of the crop. Champions are the best sort tried. Those of 1879 were an excellent crop.

Mangolds.—The crop receives four or five waterings of sewage during growth. Long Red is the favourite variety here; six pounds of seed per acre are used. It is grown on ridges 27 inches apart, and hoed out to 12 inches between plants. The yield per acre is 30 to 46 tons; they keep well for a long time in the damp. The crop seen was sown on the 3rd of May and was a very good one—the best, on the whole, of all seen during the inspection of farms.

Wheat.—This is occasionally grown here after a Rye-grass crop instead of Oats. Schole's square-headed Wheat is the variety preferred. Three bushels of seed per acre are used.

Barley.—This is grown on land manured with sewage sludge. The crop of 1879 followed Turnips; it was sown on 18th April at the rate of two-and-a-half bushels of seed per acre, on poor land. In the early part of the season it did not look well, but in the end it turned out a very good crop.

Oats.—This crop follows heavily-sewaged Rye-grass. Scotch Black Tartarian is the sort grown: the sowing at three-and-a-half bushels per acre. The crop of 1879 was sown on 4th April, and seemed a remarkable crop, looking well. In a former year oats yielded 78 measures of 46 pounds each per acre.

Market Garden.—This land receives farm-yard manure; most of the crops planted on ridges are irrigated with sewage to receive the water. Cabbages, Celery and Rhubarb are otherwise treated, as they take a considerable quantity of sewage.

5. Birmingham Sludge Farm.

The circumstances under which portions of this land are annually set apart for receiving a deposit of sludge have been explained in the section on Irrigation. Though this is a great drawback to the farming, crops of all sorts are grown.

Rye-grass.—This crop stands here for two years, and receives much sewage during growth. Three bushels of seed per acre are sown. Much of the grass of the last two years was made into hay, as there was little demand for it otherwise.

Potatos.—The land was twice prepared with sludge, but the crop was not sewaged during growth. Early Rose and Patterson's Victoria are the sorts used: the ridges 24 inches apart and the plants 10 inches distant.

Mangolds.—Several varieties are grown; six pounds of seed to the acre are drilled. The crop is irrigated once a fortnight. The average yield of 1878 was 63 tons per acre.

Kohl Rabi.—This crop has been very successfully grown here: three pounds of seed are used per acre. It is drilled in ridges like Mangolds, but is watered with sewage in dry weather only.

Swedes and Early Turnips.—These crops were less fortunate, having run to seed.

Cereals.—Of these, Oats were the most prosperous. In 1878 11 acres of Black Tartarian Oats yielded 120 bushels of corn and

2 tons of straw per acre. The crop is drilled 6 inches apart, three bushels of seed are used per acre. The Wheat and Barley are also drilled; the crop of Browick Red was good but late; the Barley was not so promising.

Vetches and Peas.—These crops are grown, but are not watered with sewage during growth.

Cabbages.—These are grown on the flat, and watered with sewage. The crop realises about £40 per acre.

LARGE FARMS

6. CROYDON.

Crops of all sorts are grown here, chiefly Rye-grass, Permanent Grass and Roots; also Market Garden crops.

Rye-grass.—This crop stands for three years and is regularly watered with sewage. It is sown either in spring or in autumn with three bushels of seed per acre.

Mangolds.—Various kinds are grown, but the Yellow Intermediate is the favourite here. The crop of 1878 was of good quality; but that of 1879 had been sown early, was injured by the water-logged condition of the land, and was very foul, presenting an unhealthy appearance.

Parsnips.—Are grown here but not treated with sewage.

Cereals.—Wheat and Oats have been grown; one field of Oats was a grand crop. These are not treated with sewage.

Market Garden.—Cabbages are very largely grown here; also Savoys and Coleworts. On some parts of the farm they are watered with sewage, in other parts not. Broccoli was grown on land that had not been irrigated for several years. Sage, Parsley and Vegetable Marrow are not watered.

Rhubarb.—This crop is largely grown here, but, contrary to usual practice on sewage farms, it is not irrigated.

Celery.—This crop is treated with sewage. It is grown from plants reared in frames on the farm, and is planted in rows 6 feet apart, the plants 7 inches distant; it is gradually banked as the plants grow.

Osiers.—Are grown in damp positions on one or two plots. French and Brown Willows are the varieties preferred; the sets are planted 2 feet by 1½ feet apart each way.

7. DONCASTER.

The crops grown here are of all sorts, including fruit shrubs; in fact they are those of an ordinary farm, on account of there not being much local demand for Rye-grass.

Rye-grass.—This crop stands two years for cutting, and the third for grazing. It is sown in the spring with a Corn crop, at the rate of two bushels of seed per acre. On the light soil it will take enormous quantities of sewage; in the year 1878 a field of 14 acres received an amount represented by a depth of nearly 14½ feet; this crop was cut for the first time in May 1879, yielding 10 to 12 tons per acre, which sold at 9*d.* per cwt. The crop was probably cut four times in that year.

Grass Land.—This is irrigated once or twice in the winter, and produces a large amount of summer food, on which the cows and young stock thrive. This pasture carries double the stock of ordinary grass land.

Mixed Seeds.—This is grown for grazing on some very poor land, which is irrigated.

Potatos.—These are grown here only in small quantities; they make much haulm, and are not irrigated during growth.

Mangolds.—The soil here is not suited to this crop; but they are grown and irrigated. They are sold by auction in October and realise £18 to £25 per acre.

Swedes.—This crop was the best seen on any of the sewage farms, and promised to be a heavy crop. It had followed Rye-grass that had stood for three years, the last crop having been grazed by sheep. Two pounds of seed per acre were drilled on the flat, 21 inches distant, and the plants were 10 inches apart in the drills. The hand-hoeing cost 8*s.* per acre: namely, 5*s.* per acre for chopping out and singling, and 3*s.* for hoeing a second time. The crop was by no means free from couch grass. It was occasionally irrigated with sewage. The Swedes are sold by auction at the end of October, and realise £10 to £18 per acre.

White Turnips.—This crop succeeds Rye, which is grazed by sheep. Two pounds of seed are sown per acre, but the crop is not directly irrigated with sewage. There is a good local demand for this crop. The ungrazed yield is sold to cowkeepers at 18*s.* per ton.

Cereals.—These were not irrigated during growth; but they contrasted markedly with those on adjoining lands that had not been treated with sewage. The Scotch Brown Wheat was a very heavy crop, and in some places lodged. Ten pecks of seed per acre were drilled. The Barley crop was drilled after Wheat with 12 pecks of seed per acre: it looked very well, and some of it was on light sandy land that had been treated with sewage. The Rye crop looked very well: 8 pecks of seed per acre had been drilled on a field of light land, and irrigated with sewage to keep off ground game. Clover and other grass seeds had been planted in the Rye. Potato-oats are also grown on this farm; 16 pecks of seed per acre are drilled.

Peas and Beans (Spring).—Neither of these crops are watered with sewage during growth; but the land is prepared before sowing with sewage. They were both fair crops for the season.

Osiers.—Long Skin Hards are grown on the low-lying flat land; they are planted in rows 27 inches apart, the sets being 12 inches distant in the rows.

8. Leamington.

Crops of all sorts can be grown here, which is managed as an ordinary farm; the irrigation with sewage being treated as an adjunct, rather than as a commanding feature, in the management of the crops.

Rye-grass.—This crop receives enormous quantities of sewage during growth (see section on Irrigation). It is not allowed to stand longer than two years; about 25 acres are sown every year at the rate of three bushels of seed per acre, usually in the autumn. A crop grown in September, 1877, was cut eight times in 1878, and twice in 1879; it was then ploughed up. The land was pressed, sewaged, and sown on the flat broadcast with Turnips and Swedes on the 15th of June, 1879; these looked well and promising during the visit in August. In 1878 the cutting of Rye-grass commenced on 2nd February. In 1879 it commenced on 7th April, having been sown in September, 1878. The first cutting yielded 4 tons per acre of green grass; the second, on the 4th of June, yielded 16 tons of grass per acre; the third, on 8th July, 14 tons; the fourth, on 14th of August, 8 tons; the

fifth, on 12th September, 6 tons; the sixth, on 6th October, 5 tons; the seventh, in November, 2 tons per acre. Rye-grass is occasionally made into hay; in that case it is carted to the meadows to finish drying. An experiment of seeding a field of Rye-grass with 10 pounds per acre of Trefoil did not succeed.

Seeds.—These are usually sown with the Straw crops. Clover is occasionally irrigated moderately in dry seasons.

Potatos.—The varieties grown were Myatt's Early Rose and Victoria. They are planted in drills 24 to 26 inches apart and 12 inches from plant to plant in the rows. The crop of 1879 was planted on 9th April, and succeeded Rye-grass that had been cut four times the year before. It was then watered with sewage broken up, and sown at the end of July with Turnips, which were grazed by sheep. The crop of 1879 was not so good as usual. This year the crop has been sold at £17 10*s.* per acre, the buyer taking all risk and raising the crop.

Mangolds.—This crop is here largely grown. It is drilled on the flat, the drills being 26 inches distant, and the plants are hoed out in the rows to 10 inches distance. Irrigation with sewage does not commence till the plants begin to bulb. In 1878 this crop received 21 waterings of sewage while under cultivation, which were equivalent to an irrigating depth of 6¾ feet, in addition to the rainfall. The Mangolds of 1878, when examined in the spring of 1879 were found good and sound, but not equal in weight and bulk to those grown on the Reading sewage farm. One field of mangolds was poor and stunted, but on the higher and light land they were a capital crop, in all cases clean, and the plants regular but late.

Turnips and Swedes.—These usually follow a Straw crop of either Wheat, Barley or Oats; occasionally greentop Turnips are cultivated after Rye-grass; these are sown broadcast at three pounds per acre, and grazed by sheep. Swedes are moderately irrigated with sewage; they are drilled on the flat with two pounds of seed per acre, the rows 16 inches apart, and the plants are hoed out to 9 inches apart in the rows.

Parsnips and Carrots.—These crops succeed, either directly or after two years, some heavily sewaged crop, either the second year's Rye-grass or Cabbage; they are grown on the level, but are

not irrigated during growth. They are drilled in rows 14 inches apart, and hoed out to 6 inches in the rows; six pounds of seed is used per acre The Parsnip crop was clean, and promised to be a fair one. The Carrot crop was not good, nor was it looking well, although it was clean.

Wheat.—A large acreage of this crop is grown here; but, as a rule, not under the influence of sewage. Taking the fields of Wheat grown during 1879: in the first example they followed a series of crops that had not been irrigated for some years; in the second example they were grown on land that had not been specially irrigated for two years; similarly also in the third example. The Wheat crop of the year of inspection was sown at the rate of two bushels of seed per acre, about the middle of October, 1878; the Wheat was seeded with one peck of Rye-grass, ten pounds of Red Clover, and five pounds of Trefoil and Alsike mixed. The plant looked well, especially the square-headed Wheat, which promised a good if not a great yield. The Browick Wheat was also good.

Oats.—This year's crop succeeded Rye-grass of two years that had been heavily treated with sewage. It had been sown on the 4th of April with four bushels of seed per acre and was not watered. The crops were heavy and lodged.

Barley.—Of the two fields of this crop in 1879, one had not been irrigated specially for two years; the other not for five years. The crop was sown on the 22nd of April with two bushels of seed per acre; it was not irrigated direct; but was a fair standing crop.

Beans.—The Winter Beans were drilled on the 23rd of October, 1878, and were poor. The Spring Beans, drilled on the 10th of March, 1879, were a capital crop. The preceding crops were very various, some having been unirrigated for years; others having been irrigated with sewage soon before. The seed was drilled in rows, at intervals of 15 inches, three bushels per acre being used. The crop was not irrigated direct.

Market Garden.—Ordinary Cabbages for market are planted on the level in rows 22 inches apart, and the plants are 17 inches distant in the rows. Savoys are similarly planted. Drumhead Cabbages are also planted on the flat in rows 26 inches apart, with 24 inches between plants. All the Cabbages are

irrigated during growth. In 1878 a crop on one field received 17 waterings of sewage, equivalent to an irrigating depth of five feet.

Rhubarb. — This is one of the permanent crops here as on most sewage farms. It costs about £50 per acre to buy roots, prepare the ground, and plant out; but the crop realizes about £40 per acre every year. The roots, however, require to be taken up every three years, divided, and replanted. They are planted 2½ feet apart, and are irrigated with sewage during growth. After the pulling for market is finished, no further use is made of the crop. The purchaser of the crop pulls and markets the produce.

Prickly Comfrey.—This is a crop grown on this farm for two years, but now given up, because the horses and cattle would not eat the produce by choice. It is a crop difficult to eradicate from the ground; young plants appear after removal of the crop.

9. Reading.

The principal crops grown here at present are Rye-grass and Mangolds on the irrigated part of the farm; but the farm has not been yet fully developed for sewage fertilization.

Rye-grass.—This crop here stands for two years, and is cut six or seven times a year. By preference it is sown on fallows in August, but sometimes in spring at the corn-sowing; the quantity of seed used per acre is three bushels. It receives large quantities of sewage during growth. It is partly consumed on the farm, and partly sold and removed; the sale in May, 1879, was at the rate of £8 per acre on the ground, ready cut.

Mangolds.—These marvellous crops grown on this farm are its most notable feature. The sorts are, the Long Red, Berkshire Prize, Intermediate, and Golden Tankard. They are grown on the level; six pounds of seed per acre are drilled in rows 27 inches apart; the plants are hoed out in the rows to 15 inches distance. It cost 15*s.* per acre to hand-hoe the plants, which are also horse-hoed thrice. The crop is irrigated with sewage until time of hand-hoeing, and in dry weather until two months or six weeks of pulling time. The

yield of Yellow Globe Mangolds in 1878 was 48 tons per acre, but these were grown on arable land after Wheat, and not treated with sewage. The crop of Long Red Mangolds in 1878 was marvellous; their yield per acre was 118 tons with tops, and 92 tons without them. They kept well and were sound and good to the last in May, 1879. They are largely consumed on the farm; but some were sold the year before at 17*s.* per ton in the field, or 20*s.* per ton delivered at Reading.

Cabbages.—These are grown on ridges 3 feet apart, the plants 1½ to 3 feet distant, according to variety. They were grown on irrigated land in 1878, but owing to the water-logged state of the land, and the severe frost, the crop was destroyed.

Cereals.—These are here grown on land not prepared with sewage, under the ordinary course of husbandry.

RESULTS OF ANALYSIS OF WATER.

AVERAGE COMPOSITION OF UNPOLLUTED SPRING WATERS (Expressed in Parts per Million).

Averages from various Strata.	Total Solids.	Degree of Tl. Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Granite and Gneiss	59·4	3·0	0·42	0·08	0·01	1·06	16·9
Silurian Rocks	123·3	6 8	0·51	0·14	0·01	1·78	18·4
Devonian Rocks and Old Red Sandstone.	250·6	12·0	0·54	0·12	0·01	7·64	38·5
Mountain Limestone	320·6	19·8	0·87	0·10	0·01	2·24	46·3
Millstone Grits and Coal Measures	219·1	13·1	0·50	0·14	0·01	3·93	18·5
New Red Sandstone	286·9	18·8	0·65	0·17	0·01	3·30	21·9
Lias	364·1	30·1	0·73	0·19	0·01	4·67	24·8
Oolitic Rock	303·3	24·4	0·43	0·11	0·01	4·02	15·5
Hastings Sand and Greensand	300·5	20·2	0·53	0·12	0	3·26	29·8
Chalk	298·4	23·6	0·44	0·10	0·01	3·82	24·5
Drift Gravel and Fluvio-marine	613·2	37·6	0·86	0·19	0·01	3·54	27·6
Simple Rain Water	29·5	0·3	0·70	0·15	0·29	0·03	2·2

COMPOSITION OF SOME POLLUTED SPRING WATERS DERIVED FROM VARIOUS STRATA (Expressed in Parts per Million).

Locality and Stratum.							
Old Red Sandstone, Lanark	99·6	3·9	1·48	0·26	0·02	2·20	18·0
Yoredale Grits, Hawes	284·6	26·6	1·74	0·33	0·05	1·31	12·0
Millstone Grits, Harrogate	79·0	4·2	1·96	0·45	0·03	0	13·0
New Red Sandstone, Bristol	1 272·8	66·9	1·86	0·30	0·01	47·12	71·0
Lias, at Oakham (Rutland)	1 018·2	88·6	2·92	1·13	0·01	3·22	18·0
Lias, Southam (Warwick)	573·0	33·5	2·82	0·54	0·11	3·97	20·0
Oolite, Beacon Spring, Bath	204·0	16·3	1·49	0·12	0	2·70	14·5
Oolite, Beechen, Cliff Bath	418·0	31·3	2·74	0·18	0	11·31	23·5
Hastings Sand, St. Leonards	419·2	16·9	2·24	0·54	0·88	4·78	96·0
Lower Greensand, Sandgate	369·0	16·6	1·46	0·30	0·01	9·55	59·5
Chalk, Amwell	284·4	16·3	6·99	0·97	0	3·02	16·0
Chalk, Morden Park, Caterham	272·6	21·5	1·38	0·29	0	6·67	14·0
Chalk, Chadwell	298·0	20·0	4·20	0·84	0·01	2·99	18·0
Chalk, Maidstone	391·6	27·9	1·38	0·44	0·04	8·70	35·0
Gravel on London Clay, Colchester	1 547·0	53·0	1·76	0·57	0·01	73·95	275·0

AVERAGE COMPOSITION OF UNPOLLUTED DEEP-WELL WATERS (Expressed in Parts per Million).

Averages from Various Strata.	Total Solids.	Degree of Tl. Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Devonian Rocks and Millstone Grit ...	326·8	17·4	0·68	0·12	0·05	2·94	27·0
The Coal Measures	831·0	35·7	1·19	0·34	0·44	2·07	108·5
New Red Sandstone	306·3	17·9	0·36	0·14	0·03	7·17	29·4
Lias	709·8	30·1	1·46	0·27	0·01	3·89	44·2
Oolites	336·0	20·6	0·37	0·10	0·22	6·25	26·9
Hastings Sand, Greensand & Weald Clay	452·0	27·3	0·68	0·14	0·16	1·96	53·8
Chalk	368·8	27·7	0·50	0·17	0·01	6·10	27·6
Chalk below London Clay	780·9	18·4	0·93	0·28	0·48	0·68	150·2
Thanet Sand and Drift	538·4	22·0	1·13	0·20	0·72	1·16	63·2

COMPOSITION OF SOME POLLUTED WATERS FROM DEEP WELLS IN VARIOUS STRATAS (Expressed in Parts per Million).

Locality and Stratum.	Total Solids.	Degree of Tl. Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Devonian, Bromyard	851·2	41·2	1·77	0·48	0	22·79	112·5
Carboniferous, Holyrood	925·4	27·9	3·26	1·75	0·56	9·50	79·5
New Red Sandstone, Lichfield	320·6	18·3	1·63	0·38	0·03	4·89	22·0
New Red Sandstone, Liverpool	867·0	35·5	1·35	0·38	0·05	86·78	126·1
Lias, Trowbridge	1 443·4	57·1	2·36	0·57	0·02	5·50	367·0
Oolites, Theescombe	274·8	21·2	1·06	0·20	0·02	7·78	25·0
Oolites, Witney	710·4	39·3	1·42	0·53	0·01	3·08	78·0
Lower Greensand, Sevenoaks	387·6	20·6	4·47	0·72	0	2·52	59·0
Chalk, Arlesey	360·0	25·0	1·70	0·84	0	11·30	18·3
Chalk, Carisbrook Castle	432·8	23·9	1·69	0·43	0·02	13·65	64·0
Chalk, Charlton	928·0	42·6	1·39	0·28	0	9·01	197·0
Chalk, Deal	2 021·4	47·2	1·39	1·37	0·65	19·76	718·2
Chalk, Gravesend	480·0	42·4	1·27	0·29	0·76	29·37	54·0
Chalk, Harwich	2 164·0	50·7	1·44	0·81	1·50	0	1 060·0
Chalk, under London Clay, Colchester	962·0	25·7	1·74	0·30	0·21	25·82	210·0
Chalk, under London Clay, Hounslow...	824·0	34·3	2·73	0·42	0·01	8·46	90·5
Bagshot Sand, Sunningdale	226·8	10·9	1·89	0·37	0·25	0	30·0

Most of these Wells were closed as dangerous.

COMPOSITION OF UPLAND SURFACE-WATER FROM UNCULTIVATED SOIL AND NON-CALCAREOUS STRATA (Expressed in Parts per Million).

SURFACE-WATERS. Stratum and Locality.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
From Igneous Rock.							
Stream above St. Neots	59·6	0·9	5·53	0·30	0·02	0	17·0
Teign above Exmouth	60·8	2·6	5·82	0·58	0·04	0	14·0
Aberdeen, Supply from the Dee	43·6	2·1	3·99	0·29	0	0	5·6
Stirling Supply, Forth	64·4	2·7	4·81	0·45	0·01	0	7·0
Dumbarton Supply, Clyde	72·6	3·8	3·86	0·71	0·02	0	8·5
From Metamorphic, Cambrian, Silurian, and Devonian Rock.							
The Camel, nr. Mulberg Tin Mine	112·4	4·0	3·36	0·60	0·08	0·32	33·5
Ilfracombe Supply, Slade	124·8	6·9	2·47	0·32	0	0·28	20·5
Bala Lake	27·9	0·4	2·27	0·01	0	0·02	7·3
Windermere Lake, Lowwood	57·8	4·0	2·99	0·76	0·02	0·18	9·9
Measand Beck (Cumberland)	21·4	2·0	1·17	0·03	0	0	...
Keswick, fm. Skiddaw..	43·4	3·4	1·32	0·24	0·01	0	10·9
Loch Ness, at exit	33·0	2·6	3·61	0·55	0·02	0	8·5
Loch Katrine	24·0	0·9	1·85	0·22	0·01	0	8·5
Ettrick, above Selkirk...	62·0	3·7	1·83	0·15	0	0·23	8·0
Glasgow, from Gorbals...	88·0	4·4	3·39	0·49	0·02	0·18	11·1
Paisley, from Rowbank	116·8	5·9	5·21	0·68	0·02	0	12·0
From the Millstone Grits and Non-calcareous Coal Measures.							
Lancaster Supply, Bleasdale	45·8	0·9	1·29	0·22	0·01	0	9·9

COMPOSITION OF UPLAND SURFACE-WATER, &c.—*continued.*

SURFACE-WATERS. Stratum and Locality.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Bolton Supply, Entwistle	93·7	5·1	2·97	0·18	0·24	0·10	11·9
Liverpool, from Rivington Pike	84·8	3·7	2·43	0·31	0·04	0	15·3
Rochdale Supply	88·2	5·1	1·34	0	0·14	0	10·9
Blackburn Supply	118·0	5·9	2·49	0·21	0	0·10	11·4
The Irwell, near source	78·0	3·7	1·87	0·25	0·04	0·21	11·5
Halifax Supply	81·4	3·2	1·33	0·31	0·05	0·29	11·0
Leeds Supply	150·0	8·3	2·58	0·25	0	0	13·0
Knaresborough, the Kidd	117·2	8·7	2·06	0·39	0	0·27	10·7
Sheffield Supply, Don...	83·6	4·4	3·56	0·57	0·01	0·32	8·5
Buxton, from Lightwood	55·4	2·2	5·09	0·41	0·03	0·14	7·0
Swansea Supply	48·4	2·3	2·05	0·25	0	0·10	11·0
Edinburgh, Crawley Burn	112·8	6·1	1·87	0·31	0·01	0	10·4
From Lower Tertiaries and Bagshot Beds							
Bournemouth Supply ...	59·2	1·8	2·82	0·39	0	0	23·5
Aldershot Camp.........	61·4	4·1	4·17	0·48	0·01	0	12·4
Ravenbourne, near Keston	131·4	5·6	4·39	0·56	0·12	0·20	26·0

COMPOSITION OF WATER BEFORE AND AFTER PURIFICATION.

Results of Analysis expressed in Parts per Million.

LONDON WATER. January and February, 1873.	Total Solids.	Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
West Middlesex Company.							
From Thames at Hampton ...	298·4	21·8	2·76	0·53	0·09	3·46	18·0
„ after Subsidence	312·2	23·3	2·09	0·71	0·05	3·29	18·0
„ after Filtration	305·6	22·1	1·98	0·43	0·01	3·35	18·0
Grand Junction Company.							
From Thames at Hampton ...	317·8	24·5	2·46	0·33	0·05	3·55	17·5
„ after Subsidence	314·2	23·6	2·62	0·42	0·04	3·56	17·5
„ after Filtration	306·8	23·3	2·31	0·32	0·01	3·45	17·5
Southwark & Vauxhall Company.							
From Thames at Hampton ...	318·4	23·6	2·85	0·50	0·02	3·31	18·0
„ after Subsidence	320·0	23·3	3·21	0·63	0·01	3·17	18·0
„ after Filtration	315·6	23·3	2·73	0·42	0	2·86	18·0
Lambeth Company.							
From Thames at Molesey	313·6	23·9	3·25	0·76	0·03	3·12	17·5
„ after Subsidence	329·6	23·6	2·73	0·67	0·04	3·48	18·0
„ after Filtration	327·4	23·6	2·58	0·38	0·01	3·61	18·0
Chelsea Company.							
From Thames at Thames Ditton	313·6	23·9	3·25	0·76	0·03	3·12	17·5
„ after Filtration *	311·0	22·7	2·58	0·32	0	3·07	17·0
Kent Company–Unpurified Water.							
New Well at Deptford	429·4	29·7	0·48	0·05	0·01	5·45	25·0
Bath Well at Deptford	354·4	26·6	0·44	0·07	0	3·63	23·0
Garden Well at Deptford	409·6	28·8	0·56	0·11	0	3·54	24·0
Well at Shortlands	306·4	23·9	0·21	0·07	0	3·54	16·0
Well at Crayford..................	352·0	25·7	0·31	0·05	0	5·05	22·5
Well at Plumstead	508·0	30·6	0·81	0·11	0	3·38	46·0
†Well at Belvidere	405·2	22·4	1·00	0·37	0	20·79	33·5
†Well at Charlton	928·0	42·6	1·39	0·28	0	9·01	197·0
New River Company.							
From the Lea Intake	344·0	25·7	2·87	0·67	0·05	3·81	18·0
„ at Hornsey Wheelhouse	329·0	24·2	3·75	0·59	0·05	3·71	17·0
„ after Subsidence and Filtration	220·0	16·6	2·27	0·43	0·02	1·86	16·5

* No Subsidence Reservoirs.

† Probably now abandoned as polluted by sewage and manure.

COMPARATIVE COMPOSITION OF WATER, &c.—*continued.*

LONDON WATER. January and February, 1873.	Total Solids.	Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Unfiltered Thames Water	246·0	19·4	1·29	0·23	0.	1·88	16·0
Thames Water Filtered through Fresh Animal Charcoal	194·0	15·2	0·29	0·07	0·13	1·94	16·0

The results of analyses of Thames water before and after passing through various filtering mediums, and filters, which were undertaken by experts at the Health Exhibition, Kensington, in 1884, are not yet available. But Spencer's Magnetic Carbide has been declared the most effective medium. There has always been much difficulty in procuring the material.

Composition of Potable Waters.

Results of Analysis expressed in Parts per Million.

North Britain.	Total Solids.	Dissolved Matters.					
		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.
Water of Streams.							
The Ness, at Loch Ness, 8 March, 1872	33	3·6	0·55	0·02	0	0·57	8·5
„ Inverness „ „	32	3·5	0·44	0·01	0	0·45	9·5
The Dee, above Balmoral, 9 March, 1872	15	1·3	0·14	0	0	0·14	5·0
The Gelderburn, above Balmoral, 9 March, 1872	20	2·0	0·19	0	0	0·19	3·5
The Don, below Alford, 11 March, 1872	57	1·1	0·26	0·01	0	0·27	12·0
The Tay, above Dunkeld, 15 Sept., 1870	29	2·7	0·13	0	0	0·13	6·8
The Tay, above Perth, 15 Sept., 1870	34	3·9	0·21	0·02	0	0·23	6·8
The South Esk, at Gladhouse Mill, 16 July, 1871	99	6·8	0·52	0·04	0	0·55	9·0
The Tala, near its source, 3 April, 1871	29	0·8	0·08	0	0	0·08	6·7
The Megget, at S. Mary Loch, 20 June, 1871	42	4·1	0·20	0·01	0	0·21	7·0
The Ettrick, above Selkirk, 2 April, 1870	62	1·8	0·15	0	0·23	0·38	8·0
The Heriot, near its source, 1 April, 1871	73	1·0	0·15	0	0	0·15	8·9
The Slitrig, above Hawick, 1 April, 1870	147	1·6	0·12	0	0·39	0·51	8·4
The Tweed, above Kelso, 4 April, 1870	89	1·6	0·15	0·02	0·59	0·76	12·0
The Elvan, above Mines, 22 July, 1870	43	0·9	0·15	0·01	0	0·16	7·5
The Leven, below Loch Lomond, 23 July, 1870	35	1·9	0·27	0·03	0	0·29	9·0
Water of Storage Works.							
Berwick water supply, 4 April, 1870	335	1·5	0·22	0·03	7·89	8·13	38·0
Dumbarton „	not	given.					
Dundee water supply, 12 March, 1872	112	4·2	0·59	0·01	0·81	1·41	17·5
Edinburgh (Swanston), 6 April, 1870	135	0·7	0·07	0	0·62	0·69	12·6
Galashiels water supply, 2 April, 1870	104	1·3	0·11	0	3·82	3·93	12·8
Glasgow (Gorbals), 3 Aug., 1870	88	3·4	0·49	0·02	0·18	0·69	11·1
Greenock water supply, 26 July, 1870	54	5·0	0·37	0·02	0	0·39	10·0
Hamilton „ 28 July, 1870	118	4·7	0·52	0·04	0	0·55	14·0
Kilmarnock „ 7 April, 1870	124	5·1	0·32	0	0·28	0·60	14·0
Paisley „ 21 July, 1870	91	2·6	0·34	0·02	0	0·36	11·2
Port Glasgow	good water, similar to that of Gorbals.						
Stirling	of excellent quality, but requires filtering.						

Composition of Polluted Waters, Waste Liquors, and Factory Effluents.

Results of Analysis expressed in Parts per Million.

Waters Polluted by Factories.	Total Solids.	Dissolved Matters.							Suspended Matters.			Total Hardness.
		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Mineral.	Organic.	Total.	
I. Pollution by Paper Mills.												
Above the highest Paper Mill in water of North Esk, 22 Sept., 1868	139.8	4.43	0.50	0.03	0	0.53	10.9	—	7.11	—	2.8	7.11
Below five Paper Mills in water of North Esk, 21 Sep., 1868	188.2	10.19	0.80	0.03	0	1.04	18.9	—	52.0	117.2	169.2	9.46
Effect of Arnot's Pond System.												
Inflow of ponds of Paper Mill at Polton Mill, North Esk, 19 Oct., 1870	594.0	90.87	17.09	0.24	0	17.29	72.0	—	154.8	165.0	320.4	—
Outflow of ponds of Paper Mill at Polton Mill, North Esk, 19 Oct., 1870	390.0	24.86	4.92	0.16	0	5.05	52.0	—	27.2	53.6	80.8	—
Effect of Reed's Process.												
Above the Mendip Paper Mill in the Axe, 18 May, 1872	232.4	1.12	0.29	0.26	1.90	1.40	21.0	—	—	—	traces	17.9
Waste liquor from Mendip Paper Mill flowing on land, 18 May, 1872	7021.	913.1	87.74	7.00	0	93.50	81.6	—	168.4	251.6	420.0	—
Below the Mendip Paper Mill in the Axe, 18 May, 1872	253.	2.45	0.58	0.34	1.95	2.81	19.0	—	3.2	2.3	5.5	18.0
Official Standard Purity	unlim.	20.00	3.00	unlim.	unlim.	unlim.	unlim.	—	30.0	10.00	—	unlim.
II. Pollution by Woollen Factories.												
Effect of Animal Charcoal Purification.												
Waste liquor from Galashiels Factory before treatment ...	1076.	489.7	33.21	4.92	0	37.26	36.0	—	241.0	779.0	1020.0	—
Effluent of do. after purification	789.	43.4	12.60	5.42	0	17.06	54.0	—	0	0	0	—
Effect of Liming and Filtration.												
Waste liquor from Huddersfield Factory, 28 Jan., 1871...	2048.	432.1	27.04	23.40	0	46.31	144.0	—	18.0	252.8	270.8	—
Do. after liming and filtration at 2.8 gallons per cubic yard of earth, 28 Jan., 1871	2212.	13.55	1.36	0.16	1.37	2.86	663.0	—	trace	trace	trace	—
Effluent of do. on 18 Feb., 1871	2305.	7.60	0.73	0.12	0.92	1.75	691.0	—	,,	,,	,,	—
Official Standard Purity	unlim.	20.00	3.00	unlim.	unlim.	unlim.	unlim.	—	30.0	10.0	—	unlim.

Factory Effluents—*continued.*	Total Solids.	Dissolved Matters. Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Suspended Matters. Mineral.	Organic.	Total.	Total Hardness.
III. Pollution by Starch Factories.												
The water of the Clyde Basin in the Douglas, 15 March, 1872	114·8	7·77	0·53	0·01	0	0·54	9·5	0	—	—	trace	6·3
Water polluted by Starch Works in the Espidair Burn, 21 July 1870	323·0	17·37	2·75	7·00	0	8·51	75·4	0·04	84·4	64·0	148·4	—
Drainage from Starch Works tanks at Paisley, 14 March, 1872	463·0	44·28	14·96	6·00	0	19·90	26·0	0·08	15·8	60·0	75·8	—
Drainage from other Starch Works at Paisley, 15 March, 1872	2276·	4670·	126·1	21·00	0	143·4	90·5	0·09	33·2	275·8	309·0	—
IV. Pollution from Bleach Works of Linen and Jute.												
Above any Bleach Works in the Dighty, 4 May, 1871	137·6	1·05	0·17	0	3·06	3·23	14·0	—	—	—	traces	9·43
Below Claverhouse Bleachfield in the Dighty, 14 Sept., 1870	1357·	67·11	17·22	0·24	0	17·42	347·0	0·52	101·	70·	171·	71·45
Below Bleachfields, Ballunie Bridge, in the Dighty, 4 May, 1871	370·	171·1	1·88	0·09	3·27	5·22	73·0	0·12	10·8	14·4	25·2	20·00
Waste liquor, of 1st boiling	43692·	7534·	526·	29·0	0	550·	717·	0·10	700·	1472·	2172·	—
" of 2nd boiling	7332·	1473·	97·	7·9	0	104·	426·	0·30	204·	366·	569·	—
" of chloride of lime	7486·	434·	63·	8·2	0	70·	—	0·10	114·	129·	244·	—
" of sulphuric acid	2886·	33·	3·	0·4	0	3·	300·	0·10	4·	13·	17·	—
V. Pollution from Flax Steeping.												
Waste liquor from Flax Steep at Avonbridge, Falkirk, 24 Sept., 1870	1675·	189·	48·	86·	0	119·	62·	0	137·	297·	434·	—
Waste liquor from Flax Steep at Baldovan, 4 May, 1871	1164·	202·	19·	17·	0	33·	43·	0·30	30·	163·	193·	—
VI. Pollution from Jute Dyeworks.												
Waste liquor from Jute Works at Dundee, 14 Sept., 1870	2365·	96·	5·	10·	0	14·	428·	0·30	178·	353·	531·	—

Factory Effluents—*continued.*	Total Solids.	Dissolved Matters.							Suspended Matters.			Total Hardness.
		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Mineral.	Organic.	Total.	
VII. Pollution from Calico Dyeworks.												
Polluted water of the Glanert below the Kelvin confluence, 25 July 1870	325·4	6·72	0·59	0·40	0	0·92	23·2	0·36	16·4	12·2	28·6	16·5
Polluted water of the Cart river below Paisley, 21 July, 1870	387·0	13·54	2·01	3·50	0	4·89	48·5	0·20	30·8	47·6	78·4	21·1
Polluted water of the Irk at Manchester, 11 March, 1869	608·0	24·52	3·52	7·59	0	9·77	83·0	0·16	37·6	46·4	84·0	32·4
Average drainage water from five Calico Print and Dyeworks	502·0	42·26	2·99	1·25	0	4·02	48·6	0·34	70·2	189·7	259·9	—
VIII. Pollution from Turkey Red Dye-Works.												
Above any Dyeworks in the Leven near Loch Lomond, 23 July, 1870	34·6	1·94	0·27	0·03	0	0·29	9·0	0	0	0	0	1·79
Below Dyeworks in the Leven near Alexandria, 23 July, 1870	49·6	3·74	0·41	0·09	0	0·48	10·7	0·06	1·3	2·4	3·7	1·79
Waste liquor from Turkey Red Works at Alexandria, 23 July, 1870	138·8	5·90	1·36	1·40	0	2·51	14·8	0·02	11·6	35·8	47·4	3·45
Waste liquor from Turkey Red Works near the Clyde, 20 July, 1870	668·0	34·71	5·10	2·00	0	6·75	28·0	32·0	278·	111·	389·	—
IX. Pollution from Sugar Factories.												
Washings of filter bags of Refinery at Greenock, 26 July, 1870	39500·	14939·	537·	trace	0	537·	—	—	7472·	18046·	25518·	—

FACTORY EFFLUENTS—*continued.*	Total Solids.	Dissolved Matters.							Suspended Matters.			Total Hardness.	Paraffin Oil.
		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Mineral.	Organic.	Total.		
X. POLLUTION FROM PARAFFIN WORKS.													
Coalpit water entering Paraffin Works, Linlithgowshire, 1 August, 1870	405·	1·6	0·39	0	0	0·39	9·9	0	—	—	trace	18·6	0
Do. leaving Paraffin Works, do., 1 Aug., 1870	515·	12·8	0·60	2·50	0	2·66	16·0	0	14·	8·	22·	18·6	4·0
General drainage from Paraffin Works, Glasgow, 27 July, 1870	125·	64·	12·5	9·5	1·24	21·6	10·0	0·20	5·	6·	11·	—	8·0
Water from Oil Separator at the same Works and date	10246·	3199·	81·5	127·8	0	186·8	—	0	26·	194·	220·	—	451·
Below Paraffin Works in the river Almond at Cramond Bridge, 15 March, 1872	258·	6·8	0·87	0·13	0·16	1·14	14·5	0·04	2·4	5·0	7·4	16·9	0·50
XI. POLLUTION FROM DISTILLERIES.													
Spent wash from Distillery at Paisley, 21 July, 1870	39378·	17057·	2373·	180·	0	2522·	—	—	836·	33372·	34208·		
Spent lees from a Distillery, 15 March, 1872	184·	22·	4·	4·	0	7·	—	—	2·	3·	5·		
Drainage from a Distillery, Port Dundas, 19 March, 1872	13006·	3812·	1085·	26·	0	1106·	—	—	51·	1140·	1191·		
XII. POLLUTION FROM CHEMICAL WORKS.		Dissolved Matters.							Soluble Sulphides.	Acidity.	Alkalinity.		
Drainage from alkali waste of Works at St. Rollox, 15 March, 1872	57668·	54·	7·64	6·	0	13·	9180·	32·	16198·	0·	·7758·		
General drainage from same Works	14165·	15·	0·17	5·	0	5·	7175·	2	trace	516·	0·		

Rural and Urban Effluents.	Total Solids	Dissolved Matters.							Suspended Matters.			Total Hardness.
		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Mineral.	Organic.	Total.	
I. Pollution by Sheep-Washing.												
Water (Tweed) before Sheep-washing	307·	3·	1·2	0·7	3·91	5·6	—	—	—	—	trace	
Pool water after Sheep-washing on the same day, 4 June, 1870	1810·	258·	39·4	19·1	0	55·2	—	—	645·	520·	1164·	
II. Limed and Manured Land.											Alkalinity.	
Effluent from farm land, Kelso, dressed with 7 tons of lime per acre	352·	1·0	0·34	0	12·06	12·40	16·0	—	—	—	0	29·1
Effluent from farm land, Moxton, dressed with 9 tons of lime per acre	354·	1·0	0·16	0·01	4·96	5·13	11·0	—	—	—	0	19·0
Effluent from field, Haymount, heavily dressed with dung	337·	1·2	0·28	0·01	8·59	8·88	27·5	—	—	—	0	30·3
III. Combined Pollution from Towns.											Total.	
The Clyde above Glasgow — 3 Aug., 1870	194·	5·0	0·67	0·07	0	0·73	15·	0·04	5·	3·	8·	
The Clyde at Govan Factory — 3 Aug., 1870	294·	12·9	1·52	5·41	0	5·97	69·	0·18	16·	12·	28·	
The Kilmarnock above Kilmarnock — 7 April, 1870	196·	5·4	0·33	0·02	0	0·35	15·	0	trace	trace	trace	
" below Kilmarnock — 7 April, 1870	322·	29·0	4·30	10·80	0	13·19	35·	0·16	15·	60·	75·	
The Slitrig above Hawick — 1 April, 1870	147·	1·6	0·12	0	0·39	0·51	8·	0	0	0	0	
" below Hawick — 1 April, 1870	207·	14·1	0·87	0·40	0	1·20	11·	trace	trace	trace	trace	

	Great Britain.		List of Formations and Groups.
	Recent and Pleistocene		Newer Alluvial gravels and Peat mosses, &c. Cave deposits and Glacial drift.
Kainozoic.	*Pliocene*		Boulder clay and older Glacial drift. Norwich crag. Red crag and coraline crag.
	Miocene		Hempstead beds.
	Eocene...	Upper	Bembridge, Osborne, Headon and Barton beds.
		Middle	Bracklesham beds and Bagshot sands.
		Lower	London clay, Woolwich and Reading beds, and Thanet sands.
Mesozoic.	*Cretaceous*	Upper	Upper white chalk, Lower white chalk, Chalk marl, Upper greensand, Gault, and Blackdown beds.
		Lower	Lower greensand. Speeton clay. Weald clay. Hastings sands.
	Jurassic ...	Upper	Purbeck beds. Portland stone and sand. Kimmeridge clay. Coral rag. Oxford clay. Kelloway rock.
		Middle	Cornbrash and forest marble. Bath oolite. Stonesfield slate and Inferior oolite.
		Lias	Upper lias. Shale and limestone. Marlstone. Lower lias.
	Triassic ...	Upper	Rhœtic. Penarth beds. Upper new red sandstone. Red shales with rock salt. Bristol dolomitic conglomerate.
		Lower	Lower new red sandstones (part).
Palæozoic.	*Permian*		Lower new red sandstone (part). Magnesian limestone, and marl slate of Durban. Trappean, breccia and red marls.
	Carbonife-rous	Upper	Coal measures of England and Wales. Millstone grit. Yore-dale series.
		Lower	Mountain limestone. Lower coal measures of Scotland. Lower limestone shale or carboniferous slate.
	Devonian		Old red sandstone. Sandstones of Dura Den, Yellow sand-stone of Ireland. Petherwyn group. Pilton, Ilfracombe and Linton groups.
	Silurian ...	Upper	Upper Ludlow and Downton limestone. Aymestry limestone. Lower Ludlow, Wenlock and Woolhope limestones. Upper Llandovery sandstone. Lower Llandovery slates.
		Lower	Bala or Caradoc beds. Llandeilo flags. Arenig or Stiper-stones group.
	Cambrian	Upper	Tremadoc slates. Lingula flags.
		Lower	Menevian beds. Longmynd group. Harlech grits and Llanberis slates.
	Laurentian		Fundamental gneiss of the Hebrides.

CHAPTER II.

CANADA.

RIVER BASINS.

NAVIGATIONS AND CANALS.

METEOROLOGY.

DOMINION OF CANADA.

RIVER-BASINS AND LAKE-CATCHMENTS.

Provinces.	Area of Land. Sq. miles.	Area of Water. Sq. miles.	Cultivable Area. Acres.	Census of 1881. Population.
Prince Edward Island ...	2 133	—	1 126 653	108 091
Nova Scotia	20 907	4 200	5 396 382	440 572
New Brunswick	27 174	—	3 809 621	321 233
Quebec	188 688	21 000	12 625 877	1 359 027
Ontario	101 733	20 000	19 259 909	1 923 228
Manitoba	123 200	—	2 384 337	65 954
Assiniboia	95 000	—	—	—
Saskachewan	114 000	—	41 216 000	—
Alberta........................	100 000	—	—	—
British Columbia and Vancouver Island	341 305	—	441 255	49 459
Total	1 114 140	—	86 260 034	4 268 364
Northern Territories not included above ...	2 356 252	—	300 000 000	56 446
Total	3 470 392	—	386 260 034	4 324 810

As it is impossible yet to obtain accurate delimitation of all the basins, and hence also to obtain their areas, the areas of provinces are given as useful adjuncts.

The navigations and canals to be mentioned hereafter being entirely in the Provinces of Quebec, Ontario, and the Winnipeg region of Manitoba, Assiniboia, and Saskachewan, the following estimation of catchment areas is confined to them.

The Divisions of the series of Catchment Basins in the main Canadian Dominion and beyond the United States boundary are estimated from the maps of 1883.

DIVISIONS.

I. The Great Lakes Catchment ....
II. The Saint Lawrence River-Basin ....
III. The Lake Winnipeg Catchment ....
IV. The Nelson River-Basin...

I. Catchments of the Great Lakes—

Groups.	Sq. miles.	Sq. miles.	Chief Rocks.
1. Lake Superior in Canada	22 550	45 256	Lower Laurentian, Huronian, and Cambrian. Much protrusive granite and a little diorite.
Lake Superior in United States	22 706		Quebec group, Chazy; a little Huronian and Trenton.
2. Lake Huron in Canada	38 702	55 276	Lower Laurentian, Huronian, Cambro-Silurian, Silurian, and Devonian.
Lake Huron in United States	16 574		Coal measures, Gaspe sandstone, Chemung and Hamilton; small quantity of Buonaventura.
3. Lake Michigan		47 344	Huronian, Niagara limestone, Gaspe sandstone, some Coal measures.
4. Lake Erie in Canada	7 973	28 739	Devonian and Silurian.
Lake Erie in United States	20 766		Gaspe sandstone, Niagara limestone, and Chemung rocks.
5. Lake Ontario in Canada	8 803	25 344	Cambro-Silurian, Silurian, and Lower Laurentian.
Lake Ontario in United States	16 541		Gaspe sandstone, Hamilton, Medina and Hudson rocks; small quantities of Niagara and Clinton rocks.

6. Surfaces of the Great Lakes.

	Sq. miles.	Altitude in feet.	Mean depth in feet.
Surface of Lake Superior	31 990	598	900
,, Lake Huron, &c.	24 210	574	450
,, Lake Michigan	23 032	578	1000
,, Lake Erie	10 510	564	90
,, Lake Ontario	7 470	234	412
Total Great Lake Surface	97 212		

II. The Saint Lawrence River-Basin—

Groups.	Sq. miles.	Chief Rocks.
1. The Ottawa Basin	62 790	Lower Laurentian, Cambrian, Cambro-Silurian; small quantities of Huronian, Trenton, Hudson, Chazy; some granite and syenite.
2. Affluents from the north-west, including all west of Point des Monts	106 476	Lower Laurentian; small quantities of Cambro-Silurian, some granite, gneiss and syenite.
3. South-east affluents in Canada, including all west of Point des Monts	20 863	Cambrian, Silurian, Cambro-Silurian, Laurentian, Huronian; small quantities of Upper Laurentian, and protrusive granite.
4. South-west affluents in United States	13 785	Lower Laurentian, Cambrian; small quantities at Trenton, Quebec, and Potsdam rock.

Groups.		In Canada.	In the United States.	Total square miles.
		Square miles.		
......	5	78 028	123 931	201 959
......	4	190 129	13 785	203 914
......	9	348 832	49 918	398 750
......	1	29 363	—	29 363
	19	646 352	187 634	833 986

III. The Lake Winnipeg Catchment—

	Groups.	Sq. miles.	Chief Rocks.		
1.	The Great Saskachewan River	91 317	Cambro-Silurian and Devonian Cretaceous, Laramie. In the mountains Carboniferous and Devonian overlying Cambrian.		
2.	The South Saskachewan River............	63 332	Cretaceous, Laramie. In the mountains as in No. 1.		
3.	Old Wives Lake Catchment	12 192	Chiefly Laramie; some Cretaceous and Miocene rocks.		
4.	Winnipegosis and Manitoba, or Western direct Catchment, including a Northwestern piece	36 920	Devonian and Silurian limestones; some Cretaceous.		
5.	Assinboine River and Qu'Appelle	64 492	Chiefly Cretaceous; some Laramie.		
6.	Red River in Canada	9 282	Cretaceous, Lower Laurentian, Devonian and Silurian limestones.		
	,, in United States.......................	36 472	Hamilton and Trenton rocks, some Potsdam.		
7.	Lake of the Woods in Canada	18 535	Laurentian, Huronian; some protrusive granite.		
	,, ,, in United States	13 446	Laurentian.		
8.	Winnipeg River and affluents	35 266	As in No. 7. Canadian portion.		
9.	Berens and Albany series, or Eastern direct Catchment	17 496	Chiefly Laurentian; a little Huronian.		
10.	Surfaces of the Larger Lakes.			Altitude in feet.	Mean depth in feet.
	Lake Winnipeg Surface	8 143	....	710	—
	Lake of the Woods Surface	1 200	....	1042	—
	Lake Winnepegosis Surface	–	Included in Catchment	770	—
	Lake Manitoba Surface			751	—
	Old Wives Lakes Surface...........	—	Included in Catchment.	Not given.	—

IV. The Nelson River-Basin—

1. From Lake Winnipeg to Hudson Bay............29 363 Laurentian, Huronian, and Silurian.

The few meteorological data given are not sufficient to establish the hydrologic condition of these regions.

NAVIGATIONS AND CANALS.

RIVER IMPROVEMENT WORKS.

The Saint Lawrence below Montreal.—The Saint Lawrence, from Montreal to the ocean, is the natural main line of navigable communication for Canada. It is, however, closed to sea-going vessels by ice for about five months in the year, and tide water reaches only to a place called the Three Rivers, 74 miles above Quebec and 86 below Montreal.

Between Montreal and Quebec there were several shoals that formerly restricted the navigable draught of vessels to 11 feet. The chief of these shoals was near the confluence of the Richelieu River, and near those of the Yamaska and Saint Francis, where is a group of numerous islands, below which the river expands itself into Lake Saint Peter, about 8 miles wide, and 40 miles long, but of small depth.

Since 1850, a channel 300 feet wide has been dredged through all obstructions, allowing the passage of vessels of 22 feet draught from Montreal to the ocean. The effect on the commerce of that town between 1857 and 1875 was very marked.

In 1876 the works of river improvement were making progress in further deepening the channel throughout to a depth of 25 feet; and thus making Montreal a port for large sea-going vessels; an advantage before confined to Quebec, 160 miles below. The dredging operations were then being carried on with the following plant:—eight dredges, costing £91 000; seven tugs, costing £14 800, and barges, scows and stone lifters to the value of £11 800; in all valued at £117 600. The cost of dredging, raising, towing and depositing is stated to vary from £13·211

per 1 000 cubic feet for small and large boulders to £4·232 per 1 000 cubic feet for soft clay.

As a necessary sequence, works of harbour construction and increased wharfage at Montreal followed the re-commencement of the works of River Improvement.

Galops Rapids Improvement.—These works commenced in 1880. Their object was to blast and dredge a channel 200 feet wide, and to give a safe navigable draught of 14 feet at low water for a distance of 3 300 feet through the Galops Rapids. These Rapids were the most shallow of the three passed by the Galops Canal (to be afterwards mentioned); the shoals to be excavated were the "Island Shoal" and the "Lower Bar."

In 1884 the passage through the former was complete. The work in the latter began in 1883. It consists in drilling, blasting and dredging the limestone rock in a depth of 10 to 20 feet of water with a current of 14 feet per second, and is dangerous and difficult.

CANALS OF THE SAINT LAWRENCE SERIES.

These are all between Montreal and Lake Ontario, being mostly short, and occurring at rapids and places where navigation on the main river would be difficult or impossible without them for vessels beyond a certain draught.

They are:—

CANAL.	Length in miles.	Least depth of water.	Fall in feet.	Name of Rapids.	Length of River between, in miles.
1. The Lachine Canal ...	8·40	13	44¾	Saint Louis.	
2. The Beauharnais Canal	11·25	9	82½	Cascade & others	15¼
3. The Cornwall Canal ...	11·50	9	48	Long Sault.	32¾
4. Farran's Point Canal...	0·75	9	4	Farran's Point.	5
5. Rapide Plat Canal ...	4·	9	11½	Rapide Plat.	4
6. Galops Canal ...	7·63	9	15¾	Galops & others.	4½
To Lake Ontario (Kingston)	—	—	—		66½
	43·53		206½		128

The three last are collectively named the Williamsburg Canals. Some of the details of each will now be given separately.

1. *The Lachine Canal.*—This canal was commenced in 1821 and opened in 1825. It extends across the southern corner of the Island of Montreal, from the city of that name to Lake Saint Louis, a wide reach of the River Saint Lawrence, above the Saint Louis or Lachine Rapids, but below the main confluence of the Ottawa River. The fall to be overcome was nearly 45 feet in a total length of 8·4 miles, but the greater part of the fall was concentrated in 3 miles. The depth of water in the canal was 5 feet, and the width 11 feet. The locks were seven in number, in cut stone, each 100 feet by 20 feet, with a depth of 4½ feet on sills. The cost of the canal was £109 601.

In 1843 the canal was enlarged, the works being finished in 1848. The depth was increased to 10 feet, the bed width to 80 feet, and the water width at surface to 120 feet. The number of locks was reduced to five, of dimensions 200 feet by 45 feet, the three upper having 9 feet depth on sills, and the two lower 16 feet. The greater depth given to the lower ones was given to admit sea-going vessels to basins connected with the canal. The total cost of the canal from its commencement to 1867 was £527 282.

In 1875 it was decided to further enlarge the Lachine Canal at an estimated cost of £1 500 000; the works began that year. Though it was at that time probable that the whole of the Saint Lawrence series of Canals would be enlarged to pass the largest vessels navigating the lakes, the enlargement was then restricted to this canal alone, for the reasons that it had to accommodate the combined traffic of the Ottawa and the Saint Lawrence Rivers, and that its lower portion required immediate enlargement for the passage of sea-going vessels to docks and wharves near Montreal.

The following details of the canal, as existing in June, 1876, during the visit of Mr. George Walch, C.E., have been gathered from his account.

The canal entrance, commencing at the harbour of Montreal, is formed by a pier of cribwork, extending for 250 feet from the south wing of the lowest lock into the river. Vessels can moor by this pier. Lock No. 1, the lowest, has an extreme lift of 13 feet. Between it and Lock No. 2 is a basin, 580 feet by 180 feet, with dressed stone walls; along the northern side of it

is a wharf. Lock No. 2 has a lift of 13 from this Basin No. 1 to Basin No. 2. The latter basin is 2 200 feet long, with a surface of nearly 14½ acres, it is lined with masonry walls, and has extensive wharfage. At its north-western end, two other Basins, Nos. 3 and 4, open out of it; these are parallel, and about 130 feet apart; their areas are 32 450 and 90 000 square feet respectively, with an aggregate of 3 590 linear feet of docking. Two "slips" or basins with pitched slopes, also open out of the canal at points respectively 100 and 700 feet beyond Basin No. 2. The canal continues through the town for nearly a mile from Lock No. 2 to Lock No. 3; it is flanked by mills and warehouses. Lock No. 3 has a lift of 8¾ feet. Lock No. 4, which is 9 400 feet beyond it, has a lift of 9 feet; near this are several mills, factories and elevators worked by water from the canal, an arrangement that creates an increased current in the canal and causes great inconvenience to vessels passing. Lock No. 5 (the guard lock) has a lift of 9 feet and is about 4⅛ miles beyond Lock No. 4; it opens into a channel formed by a cribwork pier, or wing dam, 4 650 feet long, extending up the river and parallel to the shore. This was made to raise the water at the canal exit; vessels are moored by it, and there is a small lighthouse at its extreme end. The channel leads into Lake Saint Louis.

The locks are all 200 feet by 45 feet in width between quoins. They are built of stone in hydraulic mortar and are founded on timber platforms, under which is a bed of concrete in cases where the bottom is soft. The sills of both gates are at the same level, a breast wall near the entrance to the upper bay retaining the canal bed. This mode of construction is adopted because elevated sills are unable to withstand the shocks given to gates by heavy vessels. These gates are sometimes rammed away, and the damage is easily repaired, as no injury is done to masonry below water. All the sills are timber trusses, bolted down to large cross timbers lying in trenches 8 feet below the floor; the space between them and the flooring being filled with rammed puddle.

The gates are two-leaved, not framed, but built up of solid longitudinal timbers, 18 to 20 inches thick, bolted together with large iron bolts running through the whole height of the gate, and strengthened by vertical posts or binders. There are four

wickets in each leaf for admitting water into the locks, these are 4 feet by 2 feet, and are closed by iron turning-valves worked by screw gearing at the top of the gate. No other mode of admitting water is provided (culverts in side walls are open to great objection locally; the severe frosts of Canada acting on them and injuring the walls). There are no separate heel or mitre posts; the ends of the longitudinal timbers being shaped to the quoins and mitres. The gates move on pivots at the heels, and are suspended by a wrought iron st[illegible]n each side, attached by turn-buckles to a wrought iron st[illegible]p passing round an iron pin, held directly over the centre of movement by a timber, which is bolted to the side wall and lying on it. This system of entire suspension is found far preferable to the roller system, with its liability to obstructed roller paths. But the gates are sometimes provided with rollers, clear of tracks, to be used when a suspension bar breaks. The gate tops are held in position by the ordinary arrangement of collars and anchors. These large gates work with unusual ease and smoothness.

The opening mechanism adopted for the gates consists of drag chains worked by crabs. But in two cases, the upper gates of Locks Nos. 1 and 3, are worked with the pole a[illegible]ngement so much in favour in Holland; two men working the[illegible]nderous gates with ease. The pole, a piece of hard woo[illegible] inches broad by 5 inches thick, is fastened to the leaf about 10 feet from the mitre on a vertical pin or pivot, round which it can move. It travels over three friction rollers on the coping; these are respectively $1\frac{1}{4}$, $2\frac{1}{3}$ and $3\frac{5}{12}$ feet long. A chain fastened to each end of the pole is passed round the drum of a crab, which stands on the coping across the pole, so that when wound one way the pole is forced forwards, and when wound the other way it is dragged back, at the same time turning horizontally on the pin on the gate, and accommodating itself to the varying directions due to curved movement. Under the crab the pole passes between two cheek-pieces, $1\frac{1}{4}$ feet apart, which restrain swinging, and act as stops to a pin running through the pole at the exact spot suiting the mitreing position of the gate. These are useful in holding a leaf, if the other is bumped open forwards by a heavy vessel, a case sometimes happening; they assist the clapping cell in retaining one leaf

till the other springs back into position. The pole arrangement if used for lower gates is very liable to injury from boats in the lower chamber.

Swing bridges are used throughout the canal to enable high-masted schooners and steamers with hurricane decks to pass freely. Out of six, three are over locks. They are all timber trusses, varying from 79 to 86 feet long and from $11\frac{1}{2}$ to $15\frac{1}{2}$ feet in width of roadway. That over Lock No. 2 is worked by water-power from the canal, another by horse-power, and the remaining four with gearing worked by hand.

Their construction was thus described in 1867 by Mr. J. G. Sippell. The timber bridges are formed of string pieces, braced horizontally with timber and iron cross braces, the side of the bridge forming a vertical truss, composed of diagonal cross braces of timber placed between the stringers and top rail, held in their places by iron tie-bolts, with nut and screw at each end. A ballast-box is formed at the heel of the bridge to counterbalance the weight of the toe. A gallows frame is erected at the pivot beam, over which the suspension chains pass, for supporting the toe of the bridge, when open. The length of these chains is graduated by means of screw-buckles.

Two rollers are attached to the heel of the bridge, traversing on an outer segment of cast iron, secured to a stone foundation. Rollers are also placed near the centre of the bridge, traversing on an inner segment, secured to the stone pier, for supporting the pivot. On the smaller bridges this pivot is placed in the centre of the pivot-beam, and 8 feet 8 inches from the face of the abutment wall. On the two larger bridges at Montreal, they are placed at the side, about 2 feet from the face of the wall, and secured to the under surface of the corbel below the stringer.

The works of enlargement, commenced in 1875, comprised the following intentions, which have probably been entirely carried out:—

The canal, from Basin No. 2 to Lock No. 3, to be enlarged to 200 feet mean width; between Locks Nos. 3 and 4 to 175 feet mean width; and between Locks 4 and 5 to 150 feet mean depth; the depth of water throughout to be maintained at 13 feet; excepting at entrances and in certain basins.

All the new locks to be 270 feet by 45 feet; their lifts to

remain as before, being built near the old ones on timber platforms; their sills, as before, wooden trusses, both on the same level; the top of the breast-wall, retaining the upper canal bed, to be 18 feet below water surface in Locks Nos. 1 and 2; and in the other locks 14 feet.

A new entrance to be made from Montreal Harbour, and another at the Lachine end, the latter to be 15 feet deep and 200 feet wide, formed by a continuous pier of cribwork 6 200 feet long.

Basin No. 1 (before mentioned) to be increased in depth to 19 feet; and a second basin, of the same dimensions and increased depth, to be made parallel to it and connected with it. The old Basin No. 2 to be increased in depth to 13 feet, and to have a channel 19 feet deep running through it. A new basin will be connected with it, 19 feet deep, and of dimensions 1 250 feet by 225 feet, surrounded by masonry dockwalls; this will be called the "Wellington" basin. The details of work, seen in progress by Mr. Walch, present the peculiarity of a "frost batter," or very sloping rear batter to the back of the dockwall for the topmost five feet of it. (This is intended to permit the frozen soil to travel upwards instead of pressing the dockwall outwards.)

Regulating weirs to be made in connection with each lock. These will, like all masonry works on the canal, be built on timber platforms; and in these cases they will be laid 5½ feet below water surface of the lower reach; the portion between the rear wings being covered by an extra course of 2-inch planking as a floor. Four ranges of sheet-piling, 5 feet deep, will run across the foundations. The "breast-wall" to be 4 feet wide at the top and 9 feet at the bottom; the crest 1¼ feet below upper reach level, and 49 feet long, divided into two bays by a centre pier, 3½ feet wide, to carry a foot bridge. The eight vents in the weir to be rectangular, 5 feet high and 4 feet wide, with sills at level of bed of upper reach; these will be closed by wooden gates turning vertically on centre-pivots and worked with turning rods, 3 inches in diameter. These will run through clips built into the face of the wall, up to 6 inches above the level of the wooden platform, which will be placed over the weir just in front of the breast-wall on the upstream side. The gates will close on oak frames fixed

to the edges of the vents. The upper wings and bridge pier will have grooves for stop-planks. The lower "raceway" walls will, for a distance of 70 feet beyond the end of the weir, have a plank lining 7 feet high, fastened into wall panels 2 inches deep. (This is a peculiar instance of the use of timber in Canadian hydraulic works.) The whole bed of the lower raceway will be covered by a plank flooring running under the side walls as foundations; under the floor will be several cross rows of sheet piling, 6 feet deep.

Masonry culverts to be built so as to admit of a future deepening of the canal-bed by 2 feet; that is to a depth of 15 feet of water.

In 1883 the construction of the two new basins at Saint Gabriel was commenced, and is still proceeding. The channel leading to Wellington Basin from the harbour was dredged to afford a clear navigable depth of 18 feet. The completion of the Lachine entrance, for a width of 200 feet and navigable depth of 14 feet was completed fully in 1884.

In 1884 this canal consisted of one channel with two entrances at each end, and two sets of locks, old and new. The latter are 270 feet by 45 feet, with depth on sills of 18 feet on two lower locks, and 14 on the three upper, and all permanent works are built to correspond with a navigable depth of 14 feet.

2. *The Beauharnois Canal.*—At the beginning of this century there were four short canals for navigation round the "Cascade," "Cedars," and "Côteau" Rapids: their locks were only 6 feet wide, with a depth of 2½ feet on sills; the fall to be overcome in the three rapids is in all 82½ feet in 11 miles, but mostly concentrated in 7 miles, including the two level reaches between the three rapids.

In 1817 these canal locks were enlarged to 12 feet wide, and 3½ feet deep on sills.

In 1843 the present Beauharnois Canal was begun; it was opened in 1845; and its cost, with additions and improvements until 1867, amounted to £402 856.

It begins at the foot of the "Cascade" Rapids, the entrance being formed by piers, 535 feet long, of cribwork below water level, and of a timber superstructure. The canal runs for its whole length 11¼ miles, close to the south bank of the river, entering it again

at the eastern end of the river-widening named "Lake Saint Francis," just above the "Côteau" Rapids. The water section of the canal is 10 feet deep, 80 feet in bed width, and 120 feet in surface width.

The locks are nine in number, each having a depth on sill of 9 feet, and of dimensions 200 feet by 45 feet; they resemble the old locks of the Lachine Canal, described on page 129.

The other principal works are 13 weirs, 9 timber swing bridges, of which 8 are over locks, and 10 culverts under the canal. There are recesses in the canal banks with planked vertical sides, for the convenience of ferry scows plying across the canal. The details of the works generally resemble those of the Lachine Canal.

In 1884 a railway bridge over this canal was commenced.

3. *The Cornwall Canal.*—This canal was made between 1834 and 1843 at a total cost up to 1867, exclusive of repairs and management, of £483 288.

Its entrance is at the town of Cornwall at the head of Lake Saint Francis; and it runs close along the northern edge of the river, except in two parts, each about half a mile long, where it cuts across projecting points of land. Its total length is 11½ miles, in which it overcomes the 48 feet fall of the Long Sault Rapids. The water section of the canal is 10 feet deep, bed width 100 feet, water face 150 feet. The north side of the canal is everywhere in cutting, but on the south side the water is retained and the tow-path formed by an artificial bank, founded chiefly on the bed of the river, and protected from wash on the river slope by stone-pitching, and on the canal side by dry stone facing, 2 feet above and 2½ feet below water surface. There has been much settling and sliding of this bank.

The locks are seven in number, of which one is a guard lock; the remaining six are liftlocks with 9 feet of water on sills; their dimensions are 200 feet by 55 feet. The three lowest of them are only about 200 feet apart, an arrangement liable to cause delay of traffic.

One timber swing bridge carries traffic over the canal; it is 10 feet wide and 56¼ feet in span between abutments. There are also four road-tunnels under the canal, these are 12 feet wide, 6 feet high at side walls, and 10 feet high to crown. They

are moderately effective and generally passable for foot-travellers and carriages, but they have to be cleared out once a month, and the river backs up into them.

The estimated cost of enlarging and improving this canal, to correspond with the new Lachine Canal, is £540 000.

In 1884 the new works were well advanced: the lower entrance had been enlarged; two new locks had been constructed to take the place of three old ones; also a basin 825 feet long between them. The locks were 270 feet by 45 feet with a depth of water of 14 feet.

4. *Farran's Point Canal.*—This with the two other Williamsburg canals (5 and 6) were made between 1843 and 1847; with subsequent additions down to 1867, exclusive of repairs and maintenance, they cost £330 164. The fall of Farran's Point Rapids being only 4 feet, the corresponding canal has only one lock; of dimensions 200 feet by 45 feet. The canal is only three-quarters of a mile in length, with a depth of water of 10 feet, and of 9 feet on lock sills. In 1884 the works of enlargement had not commenced on this canal.

5. *Rapide Plat Canal.*—This is 4 miles long, and has two locks to overcome the fall of 11½ feet in the rapids of the same name. The dimensions of channel and locks correspond to those of Farran's Point Canal.

In 1884 the entrance and the channel above and below the guard lock had been much enlarged and deepened. A new lock and a waste weir to the old lock had been made. The works were progressing to give a new depth of 14 feet.

6. *The Galops Canal.*—This is 7⅝ miles long, and has three locks to overcome the collective fall of 15¾ feet of the three rapids named "Point aux Iroquois," "Point Cardinal," and "Galops." Their dimensions are 200 feet by 45 feet, with 9 feet depth on sills.

The locks and other works on these three Williamsburg canals (4, 5, and 6), are similar to those on the other canals of the Saint Lawrence series before described. In 1884 the works of enlargement of the upper entrance and the deepening throughout to 14 feet were in progress. The Williamsburg canals are not used by ascending passenger steamers: these can

save two hours by keeping to mid-channel course in the river.

The estimated cost of enlarging the Williamsburg canals to the same dimensions and capacity as the New Lachine Canal is £527 000; and that of deepening the river channel in the two reaches between them, about 8½ miles, is £131 250.

From the head of the Galops Rapid to the head of the Saint Lawrence proper at Kingston, Lake Ontario, the river navigation is unobstructed, though it is intricate in some places, especially near the Thousand Islands. The distance is 66½ miles.

Remarks.—The works for improving the whole of this series of canals, from the Beauharnois Canal upwards, had not been completed in 1884, though they may be this year. When completed they will afford a navigable depth of 14 feet throughout the whole route from Montreal to Kingston.

The expense would perhaps be about two millions sterling; as for direct financial results in the form of tolls and rates, apparently they are deemed quite a subsidiary matter, as road tolls. Hence such works would in any country of transient occupation be termed unproductive, for the indirect returns and advantages might not come into full operation before the territory had lapsed to other rulers. Such a distinction fortunately does not exist in Canada, where the official Chief Engineer of public works thus reports:—

"It is well known that none of the canals have paid the interest of the money expended on their construction, or indeed very little more than the working expenses. Still, few who compare the past with the present condition of Canada will doubt that they have been of far greater benefit to the country than the aggregate amount of their cost."

Here is a clear instance of the need in every country of establishing a purely Public-works Public Debt, in shares held by its defenders, free from all risk of official misappropriation and financial swindling.

THE RICHELIEU NAVIGATION.

The Richelieu is a tributary of the Saint Lawrence, joining it at Sorel, 46 miles below Montreal, after a course of 81 miles

from Rouse's Point, Lake Champlain, which is near to, but beyond the frontier. The river forms part of a navigable route between the Saint Lawrence and New York; the remaining part consisting of 330 miles in all; 111 miles of Lake Champlain, and the Champlain and Erie Canals to the Hudson River. The traffic is chiefly in sawn timber and grain from Canada to the United States.

Part of this navigation was improved and opened in 1843; other parts between 1844 and 1849.

The lowest part of the river from Sorel to 14 miles above its confluence, appears to have been always navigable. From Saint Ours for 32 miles upstream to the Chambly Basin, a navigable minimum depth of 7 feet is maintained by a dam at Saint Ours.

The river at this place is divided into two channels. Across the main or western one the dam, made of stone-filled cribwork, is 690 feet long; it has an apron 40 feet wide of similar work, well founded in clay. Across the smaller or eastern channel is an earthen dam 300 feet long, having the water face pitched; it has a top width of 25 feet, and slopes of two to one, and the lock for navigable passage is in the middle of this dam. In freshets the water passing over the western cribwork dam is 8 to 10 feet deep.

The Saint Ours Lock is of cut stone, 200 feet long between quoins, and 45 feet wide, with 7 feet as the least depth of water on sill, and an average lift of 5 feet. Piers of cribwork extend above and below the lock for distances of 270 and 420 feet respectively.

The reach of the Richelieu from Chambly Basin, a natural reservoir, to Saint John consists entirely of the Chambly Rapids, more than 12 miles long.

The navigation is taken by a canal from the foot of the rapids for a distance of 12 miles; it has a bed width of 36 feet and a surface width of 60 feet.

The locks on it are all of masonry, nine in number, of which one is a guard lock, and the rest have a total lift among them of 74 feet; their breadth is 23½ feet, and they have 7 feet depth of water on sill. The smallest lock chamber of the nine is 122 feet by 22 feet.

The other principal structures connected with this part of the

navigation are, 6 timber bye-washes and waste-weirs, 3 culverts under the canal, 8 timber swing bridges 10 feet wide, of 56 feet span, and 1 600 feet of wharfage. The distance from the upper end of the Chambly Canal to the frontier is 23 miles.

The total expenditure on this navigation down to 1867 was £189 063, of which about a sixth was spent on the lower part at Saint Ours.

The Richelieu River above Saint John is navigable and free from obstruction up to Lake Champlain.

In 1884 some parts of the navigation near Saint John and Chambly were deepened to 8 feet; the pier at Saint John was lengthened and raised, and five lighthouses were built.

There have been several proposals to make a canal direct from Saint John to Lake Saint Louis on the Saint Lawrence above the Lachine Canal. It would certainly be the shortest and best route for traffic from the Ottawa and the upper Saint Lawrence, having a total rise of only 29 feet; but there are not any returns of the present amount of this traffic, or its probable future increase, and degree of permanence. From a strategic view, it would be extremely unadvisable.

The Ottawa Navigation.

The Ottawa River is a tributary of the Saint Lawrence, about 700 miles long from its source to its confluence; the City of Ottawa, capital town of the Dominion, is situated on its banks at about 100 miles above the confluence.

The Ottawa joins the Saint Lawrence by four channels, between which are three islands, the Ile Jésus, Island of Montreal, and the Perrot, the last being comparatively small; the channel between the Perrot and the Island of Montreal is most suited to navigation, as regards shortness of course, but there is a fall of 3 feet concentrated into a rapid between the reach of the Ottawa above the island and the Lake Saint Louis below it. The difficulties of navigation hence begin here, at about 15 miles above the upper end of the Lachine Canal.

The following are the short pieces of canal on the lower reaches of the Ottawa:—

	Length. Miles.	Fall. Feet.	Name of Rapids.	River Course. Miles.
From Lachine Canal				
1. Saint Anne Canal	$\frac{1}{8}$	3	Saint Anne	15
2. Carillon Canal	$\frac{3}{4}$	16	Carillon	27
3. Blondeau Canal	$\frac{1}{8}$	($3\frac{3}{4}$)	Blondeau	$4\frac{3}{4}$
4. Grenville Canal	$5\frac{3}{4}$	$45\frac{3}{4}$	Long Sault	$1\frac{3}{8}$
to Chaudière Falls, Ottawa				56
	$6\frac{3}{4}$	$63\frac{3}{4}$		$115\frac{1}{8}$

1. *Saint Anne Canal.*—These works, constructed between 1840 and 1843, consist actually in a mere lock with long approaches formed by piers of cribwork, situated on the Island of Montreal, to the east of the rapids. The lower approaches are piers 1 000 feet long on the land side, and 67 feet long on the river side, raised to 9 feet above water level. The upper approaches consist of a wing dam 840 feet long on the river side, extending beyond the head of the rapids; and on the land side a pier 160 feet long, with four detached guide piers beyond it. These keep the water in the lock at the level of the water in the higher reach of the river.

The old lock is of masonry, 190 feet between the gate quoins and 45 feet wide, with 6 feet depth on sills, built on a timber platform which rests on inferior sandstone. The mitre sills are of wood, the gates are solid, and the construction generally resembles that of the older locks of the Lachine Canal, before described.

The cost of these works up to 1867, including some deepening of the channel, was £33 614.

In later times, a new lock has been built in addition to the old one, with the same rise; its chamber is 200 feet by 45, with a depth on sills of 9 feet.

2. *The Carillon Canal.*—This was made between 1820 and 1828; it is on the north bank of the river; its length is $2\frac{1}{2}$ miles, its bed width was 30 feet, and surface width 50 feet.

Its locks were three in number, all of masonry: two of them lift altogether $21\frac{3}{4}$ feet, the third or upstream one dropping again 13 feet; a summit level having been made to save expensive cutting; the least depth of water on sills was 6 feet.

The cost of construction is unknown, the records having been burnt in 1852 at a conflagration at Montreal.

In later times, a dam was built across the Ottawa River at Carillon, raising the water 9 feet, and elevating the level of water in the river for 7 miles upstream. It was undermined and breached in 1883, and a very deep passage in the bed was scoured to the depth of 30 feet (?)(*sic*). In 1884 this was thoroughly repaired; and guide piers and booms added to direct rafts to the slide in the dam.

According to recent accounts the canal is now 100 feet in bed width and 110 feet wide at water surface. The locks now give a total lift of 16 feet; being two in number, each of dimensions 200 feet by 45, with 9 feet depth on sills.

3. *The Blondeau Canal* was made about the same time. It is on the north bank of the river and is one-eighth of a mile long, cut in solid rock with vertical sides; its width is 30 feet.

It has one lock cut in solid rock, and lined with dressed masonry at the quoins and recesses. Its dimensions are 130 feet by $32\frac{1}{2}$ feet, with a lift of $3\frac{3}{4}$ feet, and 6 feet depth on sill. The cost is unknown. The effect of the Carillon dam has been to reduce the lift here to zero, and to diminish the current of the rapid. Hence this canal is now used only at times of very high water, when the current is very strong. It is now proposed to improve the river channel at this place by blasting and dredging.

4. *The Grenville Canal*, also made between 1820 and 1828, is on the north side of the river; it is $5\frac{3}{4}$ miles long, partly in earth and partly in rock cutting; its bed width was from 20 to 30 feet, its surface width from 25 to 60 feet.

There were seven locks in all, of which one was a guard lock, and four were combined in two sets of two The lengths of chambers vary from 107 to 130 feet, their breadths from 29 to 32 feet; the least depth on sills was 6 feet, and the total lift of the whole was $45\frac{3}{4}$ feet. Cost unknown.

By the modern works of enlargement, commenced in 1871 and completed in 1884, this canal has been increased to 40 to 50 feet in bed width and 50 to 80 feet width of water surface, and a depth of 10 feet of water. There are now five locks, of dimensions 200 feet by 45, with a least depth of 9 feet on sills. The

old locks are now entirely obliterated. The main channel has crossing basins at intervals of half a mile, and the entr... es have been enlarged.

The details of the older works on this series of short canals present little interest; they generally resemble the construction described on the older works of the Saint Lawrence series of canals. Originally they were military works constructed under the superintendence of the "Royal Staff Corps" in order to form a communication with the Rideau River navigation, and to pass military stores by this route to Lake Ontario, and the larger lakes. They were handed over to the Provincial Government in 1853, and have since been managed by the Canadian Department of Public Works. As the Ordnance Office of Montreal was burnt in 1852, records of their cost are unavailable.

The recent works for improving the series of Ottawa canals now (1885) give a navigable depth throughout of 9 feet of water; and the locks are now increased to dimensions of 200 feet by 45.

The Upper Ottawa Navigation.—Above the Chaudière Falls, near the City of Ottawa, the river appears to be much smaller and broken by rapids for a distance of 200 miles to Matlawa.

These are the Duchesse, the Chats, the Chenaux, Portage du Fort, and the Grand Calumet, which obstruct the river as far as Culbute or L'Islet, 107 miles above Ottawa City. Here are two dams 625 feet long, and three locks, 200 by 45, with 6 feet on sills, giving a total rise of 18 to 20 feet, surmounting the Culbute Rapids; these give 37 miles of upper navigation to Des Joachims.

In 1884 shoals were removed at Grand Calumets and dams constructed at Rocher Fendu; these afford a navigable least depth of 7 feet for 80 miles to Culbute; altogether 117 miles.

The distance from the bend at Matlawa, where the river turns from south to east, to Lake Nipissing and to Georgian Bay, is very variously given according to maps.

Apparently the distance from Matlawa, along the Matlawa River and expanses, to Lake Nipissing is 35 miles, across Lake Nipissing to French River 40 miles, and the course of French River to Georgian Bay is 40 miles, with a fall of only 59 feet. In the onward course along the inner lakes to Lake Superior the

distances are to the foot of Saint Joseph Island, 150 miles, and onwards to Sault Saint Marie, 47 miles; or 197 miles of lake navigation. This seems the natural line for a very important communication between Ottawa City and the great lakes and Lake Superior, that has not yet been made. Perhaps the shallowness of Georgian Bay and the deficiency of present traffic are deemed great obstacles.

THE RIDEAU NAVIGATION.

The River Rideau is a long tributary of the Ottawa River. Its headwaters are only 40 miles from Kingston, near Lake Ontario, on the Saint Lawrence. After a course of about 86 miles in a generally direct course it discharges itself over a fall of 45 feet into the Ottawa at Ottawa City. From the headwaters of the Rideau to the headwaters of the Kataraki River is an intervening distance of only one mile. The latter river after a winding course of 40 miles discharges into Lake Ontario at Kingston. The two rivers are obstructed and consist of rapid streams spreading into deep lakes and ponds in some places; the works of river improvement and navigation consisted in removing and overcoming the obstacles and falls, by short cuts, or reaches of canal, and in uniting the two rivers by a short navigable canal.

The whole duty of keeping the water to its proper level is effected by the reserves, given below in detail. They may be divided into three systems:—

1. The supply from the Lake Wolf system to the summit level.
2. The supply from the River Tay system into Lake Rideau, which maintains the reaches descending towards Ottawa.
3. The supply from the Mud Lake system into Lake Openacon; maintaining the reaches descending to Kingston.

Lake Openacon receives the waters of Buck Lake and Rock Lake. These waters, supplemented by those of Lake Loughboro, flow into Cranberry Lake, and discharging through Round Tail outlet, form the Kataraki River. The Kataraki is made navigable by a series of dams down to Kingston.

PIECES OF CANAL, LOCKS, AND DAMS ON THE RIDEAU NAVIGATION.

Place and Distance.		Length of Cut.	Locks.		Dams.		
			Number.	Lift at low Water.	Number.	Length in feet.	Height in feet.
	Miles.	Miles.					
Ottawa	0	4·00	8	82·0	3	230 1320 1616	18 33 14
Hartwells	4¼		2	22·0	—	100	28
Hogsback	5½		2	13·5	1	320	60
Black Rapids	9½	0·13	1	10·0	1	300	12
Long Island	14¾	0·13	3	27·0	3	850	68
Burritt	40¾	1·50	1	10·5	1	240	14
Nicholson	43¼	0·50	2	15·2	1	500	9
Clowes	44½	0·05	1	10·5	1	481	16
Merrickville	46¾	0·33	3	25·0	1	150	6
Maitland	55	0·13	1	4·7	1	270	8
Edmunds	59½	0·06	1	10·9	1	343	8
Old Slys	60½	0·25	2	15·5	1	250	20
Smith's Falls	61½	0·13	4	33·7	2	600	24
Punamallie	64	1·25	1	7·8	1	260	5
Narrows	83¼	0·06	1	4·	1	600	9
Total rise at low water ...			33	292·3	19	8430	
Isthmus	87½	1·25	1	4·	—	—	—
Chaffey's	92	0·13	1	12·5	—	—	—
Davis	94½	0·06	1	9·	1	300	15
Jones's Falls	97¼	0·25	4	60·	1	300	60
Brewers Upper Mills	108	1·75	2	19·	1	200	20
„ Lower Mills	110	4·25	1	14·2	1	200	12
Kingston Mills	120	0·25	4	46·7	1	6 042	14
Kingston	126¼	—	—	—	—	—	
Total fall at low water		....	14	165·4	5	7 042	
Total		16·46	47	126·9	24	15 472	

The total length of this navigation, which was effected by the Imperial Government between 1826 and 1832, is 126¼ miles, of which only 16½ miles are artificially excavated canal, and these are in 20 separate portions; the canal portions have a bed width

of 60 feet in earth, and of 54 feet in rock, with a navigable depth of 4½ feet.

As much of the line consists of broad expanses of water, there are not any tow-paths, and steam is the only motive power used.

The total number of locks in the whole navigation is 47. Those ascending the Rideau are 33 in number, with a total lift of 282½ feet; and those descending the Kataraki are 14 in number and have a total descent of 164 feet at high water.

The locks are 134 feet by 33 feet, with a navigable depth on sills of 5 feet, but the water is seldom kept up throughout the year to full height.

There is a full description of the works on this navigation in the earlier volumes of the Papers of the Royal Engineers; but the following details are given by Mr. George Walch, C.E., who visited the works in 1876.

The entrance from the Ottawa River is by a flight of eight combined lock-chambers. Situated at the mouth of the rocky ravine running at the foot of the hill crowned with the Parliamentary Buildings. The total lift of this flight of locks is 82 feet.

In all the locks of this navigation the chambers are 134 feet long from mitre to mitre, and 33 feet wide, with 5 feet depth of water on sills. The walls are of ashlar, and between them is a stone invert. The gates are ordinary double-leaf gates, worked by balance beams, which are moved by chains attached to their ends, and winches. Water is let in and out of the lock through a culvert 4 feet by 3 feet, running round the back of each gate; the valves closing these are worked by crab-winches and chains. As the gates have not any suspension bars or diagonal ties, they probably run on rollers.

At 4½ miles above Ottawa are two more combi[illegible] the former, and above these is a cut-stone was[illegible]eir with an overfall of about 18 feet down to a slop[illegible]on, at the bottom of which is a timber floor [illegible] at full water level, and has not any shutter[illegible] of the breast-wall is a gap, running down [illegible] level, [illegible] in width closed by planks.

At about a mile above this, the canal joins the river, which

is ponded back for 4 miles by an earthen dam 320 feet long and 50 feet high. (At this place two or three masonry dams have been carried away.) At the end of this dam is a wooden bulkhead with 5 openings of 20 feet each in width, their sills being 16 feet below water surface. These openings are closed by stop-logs dropped into grooves, and lifted with chains and winches. The apron below this bulkhead is 100 feet long; it is a timber floor on cribwork bolted down to the rock, and from its edge there is a pitch of 15 feet on to rock. Both bulkhead and apron showed injury from ice and logs. Beyond the bulkhead a bye-wash, 150 feet wide, affords an escape for excess of water into the river-bed. At this place, known as "Hogsback," are two combined locks, the walls of which are bulged and cracked.

Near Kingston Mills, at the southern end of the navigable route, the River Kataraki has, at the head of some falls, been dammed and ponded up for about 10 miles by an embankment nearly a mile long, and in parts 20 feet high. On the lower side of this bank was a dry stone retaining wall 15 feet high, 9 feet thick, built of flat limestone slabs on edge, having their true beds all vertical; it was standing well. The escape-weir of this pond has a crest 20 feet long, on which stop-logs are dropped into grooves, and are lifted with a winch and chains at each end. Out of the lake above the embankment, one lock drops into a masonry basin, and from that a flight of three chambers combined drops 45 feet into the bed of the stream, the channel of which is used for navigation down to Kingston Harbour, a distance of about 5½ miles.

In 1883 the dam, waste-weir, lock and bridge were seriously damaged; they were replaced and rebuilt in 1884.

The actual cost of the works down to original completion was £803 774; subsequent improvements until 1867 raised the amount to £1 020 632. The traffic is small on this navigation, which is of military and strategic value, but as it saves no distance either as a westward or as an eastward route, is of local rather than of general use.

In 1884 proposals were made to connect Gananoka town by a branch navigation with the Rideau system; also to augment the supply to the Rideau at Bedford Mills by new branches from some lakes on the Devil Lake system.

The Tay Canal.—This will, when finished, be a branch of the Rideau system, affording communication from Beveridges Bay on Lake Rideau, to Perthtown, a distance of 6 miles; it involves one dam, two locks, and the deepening of the River Tay; these were not quite completed in 1884.

THE TRENT NAVIGATION.

This was projected by Baird in 1835, but only partly executed. It still consists of an unconnected series of river reaches and lakes between Trenton, at the mouth of the Trent, on Quinté Bay, Lake Ontario, to Georgian Bay, Lake Huron.

In 1837 the works were commenced for carrying out a complete navigable communication through the River Trent, Rice Lake, the River Otonabi, and Lakes Clear, Buckhorn, Chemong Pigeon, Sturgeon, and Cameron to Lake Balsam, "the summit water," about 166 miles from Trenton. From Lake Balsam by a canal and the River Talbot to Lake Simcoe, and onwards by the River Severn to Georgian Bay. Altogether 235 miles.

The execution of the works being afterwards deferred, parts of the navigation were completed, as shown in the list, by means of certain detached works, also mentioned.

Reaches and Detached Works.	Distances.		Length of Reach.
	Miles.	Miles.	Miles.
Trenton to Nine Mile Rapids	—	9	9 Unnavig.
Chisholm's Canal lock and dam ...	$15\frac{1}{2}$	—	—
Nine Mile Rapids to Percy Landing ...	—	$28\frac{1}{2}$	$19\frac{1}{2}$ Navig.
Percy Landing—boom	$28\frac{1}{2}$	—	—
Percy Landing to Heeley's Falls ...	—	$42\frac{3}{4}$	$14\frac{1}{4}$ Unnav.
Campbellford—booms	$34\frac{3}{4}$	—	—
Middle Falls—4 dams and 2 slides ...	$37\frac{1}{4}$	—	—
Crowbay—boom	38	—	—
Heeley's Fall—dam and slide ...	$42\frac{3}{4}$	—	—
Heeley's Falls to Peterboro'	—	$94\frac{1}{2}$	$51\frac{3}{4}$ Navig.
Crook's Rapids—lock, dam and slide	$84\frac{5}{8}$	—	—
Whitlar Rapids—lock, dam and canal	$92\frac{1}{8}$	—	—
Little Lake—3 piers and a boom ...	94	—	—
Peterboro' to Lakefield	—	104	$9\frac{1}{2}$ Unnav.
Burleigh—timber slides	101	—	—
Lakefield to Burleigh	—	116	12 Navig.

Reaches and Works—*continued.*	Distances.		Length of Reach.
	Miles.	Miles.	Miles.
Burleigh Rapids	—	117	1 Unnav.
Burleigh Rapids to Buckhorn Rapids ...	—	124	7 Navig.
Buckhorn Rapids	—	125	1 Unnav.
Buckhorn Dam	125	—	—
Bobcaygeon—dams, locks and canal	140¾	—	—
Fenelon Falls—slide and boom ...	155¾	—	—
Lindsay Lock	161¼	—	—
Buckhorn dam to Lindsay	—	161¼	36¼ Navig.
BRANCH OF NAVIGATION.			
From Lindsay to Port Perry at head of L. Scugog.	—	190	28¾ Navig.

Out of the whole 190 miles, 155 miles of detached reaches were navigable for vessels of light draught.

In 1855 parts of the works were transferred to a committee of traders in lumber; but eventually were reassumed by the Government, as they failed to carry out the conditions.

In 1879 the old Lindsay lock became useless and the Government of Ontario built a new one 134 feet by 33 with 5 feet of water on sill; this re-extended the navigation to Port Perry. It was intended to follow this type of lock throughout this route.

In 1884 the works for completing this navigation were in progress. At Burleigh Rapids a canal of 2¼ miles; at Buckhorn Rapids and at Fenelon Falls two short reaches of canal. New dams to replace the old ones at Lakefield and Young's Point, five miles above. Their completion will open the route from Lakefield to Balsam Lake, and thus form 150 miles of continuous navigation from Heeley's Falls to Port Perry.

SHORT PASSAGES.

The Murray Passage.—This is now being made. It will be 4⅛ miles long, with two entrances, altogether 9½ miles of work. It is a cutting from the Bay of Quinté through the Isthmus of Murray ending at the village of Brighton, in Presqu'île Harbour. It was commenced in 1882.

Burlington Bay Passage.—This is another navigable passage half a mile long through a sandbar separating Burlington Bay from Lake Ontario. Its width varies from 108 to 138 feet, and its navigable depth is 10 feet. It gives access to Port Hamilton, also through the Desjardins canal to the town of Dundas, and is in full operation.

THE WELLAND CANAL.

This is at present the most important of the Canadian canals as a detached work. Its object is to afford a navigable communication for large vessels between lakes Erie and Ontario; the ordinary watercourse being the River Niagara, with a cataract of 316 feet and several miles of dangerous rapids, having a total fall of 330 feet in 30 miles.

In the neck of land between the two lakes, which is about 35 miles broad, and nearly double that in length, there is a transverse river, the Chippewa, also called the Welland, which discharges into the navigable part of the Niagara River below Navy Island and above the great Niagara Fall.

In 1829 the first canal, made by a private company in five years with help from Government, was opened. Its course was from near the mouth of the Welland down to Lake Ontario, probably near the end of the existing canal, and it passed vessels of 85 tons burden. But landslips occurred in the deep cutting, thus stopping further traffic.

In 1833 works of improvement and extension of the canal were completed, partly on a fresh course. The extension from the Welland to Lake Erie at Port Colborne was opened, as well as a feeder 22 miles long from Dunville on the Grand River; but at that time the locks were all of wood, and of dimensions varying from 110 feet by 22, to 130 feet by 32, with a navigable depth of 7½ feet only.

In 1841 the Government acquired the canal by purchase at a total cost of £462 857; and works were recommenced the year following.

In 1845 some enlarged masonry locks were opened, of dimensions 150 feet by 26½ feet, with 9 feet depth of water on sills; and the whole canal, with its 26 locks, was finished in 1850.

During the succeeding 17 years various improvements were

effected, deepening the depth on sills to $10\frac{1}{4}$ feet and widening to 50 feet, bringing it up to its condition in 1867, when steamers of 400 tons could pass through.

The following is an account of the older works existing in 1876.

The canal has three separate navigable entrances, the chief one at Port Colborne; the second at Port Maitland near the mouth of the Grand River, also on the Lake Erie side; the third at or near Chippewa, a small port on the Niagara River, two miles above the Falls. The supply of water for the canal is taken from the Grand River at Dunville, conveyed by a cut to near Port Maitland, and onwards into the main canal by the feeder branch. The exit from the canal into Lake Ontario is at Port Dalhousie, nearly due north of its entrance from Lake Erie. The length of canal and navigation may be thus estimated in detail:—

Main Canal.	Length, miles.	Depth, feet.	Rise, feet.
From shore of Lake Erie to Colborne Lock No. 27	$\frac{1}{8}$	$10\frac{1}{4}$	8
From Lock No. 27 to Junction	$7\frac{1}{2}$	"	Summit level above level of Lake Erie.
From Junction to branch into Chippewa River	1	"	
Onwards to Port Robinson, and second entrance to Chippewa River	$3\frac{3}{4}$	"	
			Fall.
Onwards to Allanburgh Lock, No. 26	$2\frac{1}{4}$	"	$15\frac{1}{4}$
From this to Thorold Lock, No. 25	$3\frac{1}{8}$	"	$13\frac{1}{3}$
From this to Twelve-mile Creek	$5\frac{3}{4}$	"	306
Onwards, to Lock No. 1, near Lake Ontario	$3\frac{1}{2}$	"	0
	$27\frac{1}{4}$		$326\frac{3}{4}$
Grand River Feeder and Branch.			Fall.
Dunville supply channel to Junction	5	9	—
From Junction to junction with main canal	16	9	—
Branch to Port Maitland	$1\frac{3}{4}$	9	$7\frac{1}{2}$
	$22\frac{3}{4}$		
Chippewa Navigation.			
From Port Robinson to Port Chippewa	$8\frac{3}{4}$		
Altogether	$58\frac{1}{4}$		

The bed width of the canal varies from 50 feet to 70 feet; in the rock cutting where the sides are vertical it is 58 feet; and through the rest of the "summit level," including the "deep cut," 1¾ miles long between Port Robinson and Allanburgh Lock, it is 50 feet wide. The canal is regulated for the passage of vessels 145 feet long, 26 feet broad, and 9 feet draught; the tonnage of the largest vessels using it is 400 tons, but they seldom carry more than 300 tons, or 4 000 barrels of flour or 18 000 bushels of grain.

There are 24 locks 150 feet by 26½ feet; 2 large locks, Nos. 1 and 2, which are 200 feet by 45 feet, and a guard lock, No. 27, which is 230 feet by 45 feet; the least depth on sills is 10 feet. The details of these and other works, now superseded by modern improvement, correspond to those of the Lachine Canal generally, which have been described.

The entrance from Lake Erie is formed by piers of cribwork, the western one 1 600 feet long, the eastern one 500 feet; at the shore line they are 150 feet apart. At the land end of these piers is a basin 1 475 feet long, extending to Port Colborne Lock No. 27; the basin has an average width of 265 feet, and a depth of 11 feet to 18¾ feet, varying with water level of the Lake. Colborne Lock has a rising lift of 8 feet to a summit level reach, which extends for 14½ miles to Allanburgh Lock No. 26. In dry seasons the supply from the feeder is barely enough to maintain the navigable depth required. The existing depth of cutting through the ridge of land is 45 feet, and, unfortunately, 15 feet deep of spoil has been piled near the edge of this, making in all 60 feet; while the soil, composed of stiff clay resting on shifting sand, is liable to landslips.

After the fall of 15½ feet at the Allanburgh Lock is a reach crossing the "Beaver's Dams Creek" between high embankments, passing "Marlatt's Pond," a natural sheet of water, and ending at Thorold's Lock No. 25. The next reach passes through the village of Thorold and descends 306 feet by means of 24 locks in a distance of 5¾ miles; dropping at the end into "Twelve-mile Creek," which is ponded up by a dam at its outlet near Lake Ontario for 3½ miles. Lock No. 1 passes the navigation from an inner basin of about 40 acres, by this ponded creek, into an outer basin of about 8 acres. From this, crib-work piers 1 800 feet long and 200 feet apart run out, pre-

serving a sheltered channel, which is maintained by dredging, into deep water in Lake Ontario.

The branch and feeder from Dunville has a navigable depth of 9 feet throughout its entire length; the aqueduct across the Chippewa River is about one mile below the junction of the branch; it has four arches of 40 feet span and 7 feet rise; near this is a lock having a drop of 17 feet, communicating with the Chippewa River.

The towing on the long "summit level" reach is generally done by steam tugs, that on the short reaches between locks by horses. The trip through the main canal takes 20 to 24 hours in steamers, and 30 to 48 hours in towed sailing vessels. The cost of the works up to this period of complete construction in 1867 is said to be £1 527 648. For several years after the construction of the works just described, the canal and its locks were large enough for all craft then existing on the lakes. In modern times economy of freight has caused larger steamers and vessels to be made there, which could not pass through.

In August, 1873, new works were commenced at an estimate of £2 310 000 for enlarging the Welland Canal so as to render it fit for the passage of the largest vessels likely to navigate the lakes 250 feet long, 38 feet broad, and drawing 14 feet of water; with a depth of hold of 21 feet.

The size of such a vessel was then determined from local economic considerations, being larger than the Erie Canal could pass, and about the largest that could conveniently pass into Lake Huron and the upper large lakes over the various rapids and shallows, and would admit of easy handling in the lake harbours. But before the completion of some of the enlargements in 1881, far larger vessels were used on the upper lakes for economy of grain transport: about 20 vessels existed of more than 1 500 tons while 40 vessels of more than 2 000 tons were then being built.

Thus the providential arrangements did not include everything; while as regards passage of 1 500 ton vessels to the ocean for winter employment, the shallowness of the Cornwall and Beauharnois Canals presented a further obstacle to be remedied.

In August, 1881, the works of enlargement were so far complete as to allow of the use of the Welland Canal in its altered and enlarged condition.

The Recent Works.—Among the achievements effected are :—

1. The supply of the whole canal direct from Lake Erie.
2. The enlargement of the bed width to 100 feet, and the depth to 15 feet of water.
3. The enlargement of locks to dimensions 270 feet by 45 feet, with depth on sills of 13 or 14 feet; all of them being single locks, and having regulating weirs attached.
4. The separation of all locks by reaches of 1 000 feet, originally determined, has not been rigidly adhered to; a few are about 800 feet apart.
5. The construction of side reservoirs and side channels to reduce the immediate loss of navigable depth in short reaches caused by lockage.
6. A new alignment of canal from Allanburgh Lock down to Port Dalhousie, with longer and more gradual descent.
7. Extensions and improvements of the harbour and basins at Port Colborne.

The new portion of canal from the junction to Port Dalhousie is $11\frac{1}{8}$ miles long; while the total length from Port Colborne to Port Dalhousie is $26\frac{2}{7}$, saving nearly three-quarters of a mile of distance, as the old line was tortuous, though the detour from the straight was less in the extreme.

The summit level of the new canal extends from above Thorold, though it was originally intended to deepen and use the old reach of $3\frac{1}{8}$ miles. The trace passes then through a ravine forming the head of the "Ten-mile Creek," and descends the Niagara escarpment at the bend it forms at the extreme east of the canal trace.

From this point it turns to the north-west and has a nearly straight reach to a point east of St. Catherine's Cemetery, where it bends again to the west. Partly following May's Ravine, the new canal has its third and last reach, which ends in the harbour of the "Twelve-mile Creek," opening into the basin of the old canal, about half a mile from Port Dalhousie.

There are 25 locks in the new canal, of which 7 are below St. Catherine's, and 18 above it; also one guard lock.

The extreme difficulties imposed by the railways and roads have been met by six swing bridges passing over the canal and two tunnels passing under it. The extensive modification of the

aqueduct over the Welland River down to a lower level is a matter requiring plans for explanation.

The estimated cost of this part of the works (the new portion) was £1 295 000; the estimated quantities were:

	Cubic Rods.*		Squares.*
Earthwork	94 500	Planking, reduced to 1 inch thick by Board measure.	40 000
Rock	4 725		
Masonry	8 910		
Timber	1 000		

Proceeding to details of these works on the new portion of canal:

The side slopes of the canal, both in bank and in cutting are 2 to one, without any berm; the tow-path is 15 feet wide and 3 feet above water surface; the inner slope is protected against wash by a pitching of quarry chips, for two or three feet above and below water level. In the work of excavation, ploughs and excavating scoops drawn by horses were largely used for surface work; for facework in earth in deep cuttings, the "Otis" scoops, worked by portable steam-engines, were used; for facework in rock, steam drilling and blasting was followed by the use of the Otis scoops in the same way. In dredging the channel in Dalhousie harbour, the Otis dredgers brought up clay and loaded "Scows" and mud barges with it.

All the locks, even on stratified limestone, are built on platforms of pine timber. On a very soft bottom, concrete is laid below the platform. Baulks one foot square are laid half a foot apart, the spaces are filled with concrete or rammed puddle; over them is laid a three-inch course of planking, over that a two-inch course of planking. Under sill trusses the baulks are laid side by side and screwed together with wrought-iron screw-bolts. There are also rows of sheet-piling five feet deep at the upper and lower ends of each sill, and at the lower end of each tail-bay. In sound rock the sills are bolted down to the rock.

The masonry in the lock walling is made of a blue limestone quarried near the Niagara escarpment; also of a light grey limestone from the bank of the Niagara; the coping-stone from Point Pelée on Lake Erie. The mortar used is one part of hydraulic cement, made from stone near at hand, and two parts of coarse

* The Cubic Rod of 1 000 cubic feet, and the Square, or Square Rod, of 100 square feet, are the units above used.

sand. All backing consists of stones not less than four square feet in area and half a foot thick, laid level, no pinning being allowed. Puddle three feet thick is put at the back of the walls. The details of the design of the locks can be best obtained from drawings.

The lock gates resemble those of the newer sort on the Lachine Canals already described; they are worked with drag chains and winches, and have pairs of cast iron valves, worked with cranked rods, for letting water in or out. Culverts are not used at all for this purpose.

The regulating weirs are built on timber platforms, close to each lock, and have an upper and a lower channel attached for receiving water from an upper reach and discharging into a lower one; these with the side reservoir beyond the weir form the regulating works. Their spillways are 58 feet long and their details resemble those on the Lachine Canal generally.

The swing bridges are built on timber platforms, and have roadways 15 feet wide; the rest-piers, 6 feet wide, are in the middle of the canal, but have a through archway for passing water. The tunnel for the Great Western Railway is 16 feet wide, with a clear height of 18 feet above rail level to crown of arch. The arch is composed of limestone blocks in a ring 26 inches deep.

The drainage works are very small, as the canal is nearly parallel to the chief drainage line of the tract of country. The small amount to be dealt with is mostly diverted, and passed in an inverted syphon of two arched vents, each of 8 feet; the foundations for these are of timber (*sic*), laid 10½ feet below the bed of the canal; there is a fall of three feet between the top of the upstream well and that of the down stream well. The whole culvert is covered with a bed of puddle 2 feet thick.

The improvements at Port Colborne consist of an extension of the basin to an increased area of 12 acres and depth of 15 feet; a channel entrance 15 or 14 feet deep; and a new outer harbour of 40 acres formed by a breakwater 2 000 feet long on a reef running out from the shore in a diagonal direction.

The improvements near Port Dalhousie, in the harbour of the "Twelve-mile Creek," consist of an enlargement of the basin to an area of 16 acres, and of its depth to 17 feet; thus providing shelter for more than 100 vessels.

Probably some further improvements and alterations were made after 1881; but about this progress details are not given.

In 1884 the condition is thus stated in the Annual Report:—Passage is now afforded, at all stages of water level in Lake Erie, to vessels drawing 12 feet of water, except at the point where the canal is in aqueduct over the Chippewa River. Here the necessity of using the old work during the building of the enlarged aqueduct renders care needful; self-propelling vessels should not exceed $11\frac{1}{2}$ feet in draught, and vessels in tow 12 feet. Also, during strong easterly winds, combined with low water level in Lake Erie, the draught of any vessel should not exceed $11\frac{1}{2}$ feet. The Welland Canal has one entrance from Lake Ontario at Port Dalhousie, and two entrances from Lake Erie; one for the main canal at Port Colborne, the other for the feeder at Port Maitland; it has also still an entrance from the Niagara River at Chippewa town. The enlarged route lies between Port Dalhousie and Port Colborne; from Port Colborne to Allanburgh, 15 miles, there is one enlarged channel; from Allanburgh to Port Dalhousie, $11\frac{3}{4}$ miles, there are two channels, the old one and the new one.

The details in 1884 were thus:

Main Canals.

Total length of canal in miles	$26\frac{3}{4}$ miles
Number of locks (excl. 1 guard lock)	25
Dimensions of locks	all 270 × 45 feet.
Total fall between lakes	$326\frac{3}{4}$,,
Depth of water on sills in feet	12 ,,

Welland River Branches.

Length from Port Robinson Cut to River Welland ...	2 622 feet.
From Canal at Welland to river by Aqueduct lock ...	300 ,,
From Chippewa Cut to River Niagara	1 020 ,,
Number of locks: 1 at Aqueduct, 1 at Pt. Robinson ...	2
Dimensions of locks	150 × $26\frac{1}{2}$ feet.
Total fall from Canal to River	10 ,,
Depth on sills	$9\frac{5}{8}$,,

Grand River Feeder.

Length of canal	21 miles.
Number of locks 2; Dimensions ...	150 × $26\frac{1}{2}$ and 200 × 45 feet.
Total fall to junction	7 to 8 ,,
Depth on sills	9 ,,

Port Maitland Branch.

This is $1\frac{3}{4}$ miles long, and has 1 lock, 185 by 45 feet.
The total fall is $7\frac{1}{2}$ feet, and the depth on sill 11 feet.

Half the new Aqueduct was finished and used; and the rock cutting between Humberstone and Port Colborne was nearly completed in 1884. The minimum depth on sills at ports was thus during the season of 1883:—

	Old lock.	New lock.	
Port Colborne	12 feet	14 feet	in November.
Port Dalhousie	13 „	$15\frac{1}{3}$ „	„

Sault St. Marie Canal.—This is a short canal across a point of land at the entrance to Lake Superior; it is about a mile in length, and has one lock with the large lift of 18 feet. Its chamber is 515 feet long and 80 feet wide, with 16 feet depth of water on sills.

This canal is in United States territory; but is here mentioned as it completes the chain of navigable communication, and as there is not any corresponding canal on the Canadian side of the frontier that serves the same purpose.

PROJECTS.

Connection with the Winnipeg Catchment.—After the future completion of any intended Canadian navigable communication into Lake Superior, independent of the Saint Marie Canal, the next important extension should evidently be a navigable opening into the Winnipeg series of navigable communications.

It is noticeable that the frontier line on the west of Lake Superior falls most unfortunately as regards the public advantage both to Canada and the United States. There are wedges of the Winnipeg catchment belonging to the United States; while further west, strips of the Missouri catchment are in Canadian territory; a state of things requiring mutual concession and re-adjustment in the interests of both countries.

The Winnipeg catchment possesses great advantages in natural lines of waterway; the Great Saskachewan River rising in the Rocky Mountains is 1 500 miles long, of which the 1 000 miles below Fort Edmonton are navigable for steamers; the South Saskache-

wan River is navigable below Medicine Hat to its confluence; the Red River of the North is navigable for 400 miles; also parts of the Qu'Appelle and the Assiniboine for 320 miles. Lake Winnipeg, 280 miles long, discharges into the Nelson River, which affords a short communication of 212 miles with Hudson Bay, where it discharges at a port, partly blocked by a sand bar, which is open for four months in the year to ocean traffic.

The connecting navigation (Superior and Winnipeg) would not be excessively costly in construction.

Through Ship Route.—The entire navigation comprised in the before-mentioned existing and intended parts, would extend from Quebec through Lake Superior and Winnipeg to Port Nelson in Hudson Bay. Eventually sea-going vessels of 1 000 tons should be able to pass through. The early completion of this achievement will create the prosperity of the Dominion on a scale not to be attained by any amount of railway extension. It is not possible to obtain the distances and heights above mean sea level of points all along this route with accuracy; the following are partly approximative.

	Distances.	Elevation.		Distances.	Elevation.
	Miles.	Feet.		Miles.	Feet.
Tidewater at Three Rivers	0	0	Amherstburg	692¾	—
			Windsor	710¾	—
Montreal	86	12	Foot of S. Mary's Island	735¾	—
Lachine	94½	56¾			
Beauharnois	109¾	139¼	Sarnia	768¾	—
St. Cecile	121	—	Foot of St. Joseph's Island	1 038¾	580
Cornwall	153¾	187¼			
Dickinson's Landing	165¼	—	Head of Sault S. Marie	1 086¾	598
Farran's Point	170¼	191¼	Pointe aux Pins	1 093¾	—
Upper end of Croyles Island	171	—	Port Arthur	1 359¼	598
			Lake Shebandowan	1 405	—
Williamsburg	181½	—	Kawatin	1 705	—
Head of Galops Rapids	197⅝	218½	Winnipeg Lake, Ft. Alexander	1 825	710
Prescott	205	—	Playgreen Lake	2 105	710
Kingston	264	234	Port Nelson Harbour	2 317	0
Port Dalhousie	434	234			
Port Colborne	460¾	564			

Of the difficulties presented by any project of a through ship route, there is no doubt. A navigable depth of 14 feet throughout would be necessary. At present it is said that generally throughout Lake Winnipeg the ordinary navigable depth is 12 feet; though a deep channel might be found. As to the course of the Nelson River; this falls 710 feet in 312 miles, draining an area larger than the Gangetic basin, it is obstructed by numerous falls and rapids, both above Split Lake and below it; and terminates at Port Nelson an open roadstead, 160 miles from the nearest good natural harbour, Churchill Harbour. The difficulties would, however, not be insurmountable nor inconvenient for descending vessels; there are, besides, alternative routes, one below Split Lake by the Little Churchill River to Churchill Harbour, the other by Knee Lake and Hayes River to York Factory.

At one time the idea of ocean-shipping traversing the Saint Lawrence was deemed chimerical.

Other future Projects. — Among these, the most probable appear to be:—1. A short cut from Lake Winnipegosis to Cedar Lake. 2. A short cut from the river Assiniboine into the Swan River near Port Pelly. 3. The improvement of the Qu'Appelle river. 4. A supply to the upper part of the Qu'Appelle river from the Old Wives' Lake catchment, and perhaps also from the South Saskachewan River at The Elbow or at Thunder Creek. If these latter are practicable, the next would be: 6. Through navigation by the Qu'Appelle and the South Saskachewan to Medicine Hat, and perhaps higher, to near the foot of the lower ranges of the Rocky Mountains.

DATES OF OPENING AND CLOSING OF NAVIGATION ON THE CANALS FROM 1858 TO 1882, INCLUSIVE.

Year.	Lachine Canal. Opened.	Lachine Canal. Closed.	Lachine Canal. Number of days open.	Beauharnois Canal. Opened.	Beauharnois Canal. Closed.	Beauharnois Canal. Number of days open.	Cornwall Canal. Opened.	Cornwall Canal. Closed.	Cornwall Canal. Number of days open.	Williamsburg Canal. Opened.	Williamsburg Canal. Closed.	Williamsburg Canal. Number of days open.	Welland Canal. Opened.	Welland Canal. Closed.	Welland Canal. Number of days open
1858...	Apr. 25	Dec. 1	221	Apr. 26	Nov. 26	215	Apr. 26	Dec. 7	226	Apr. 25	Dec. 11	231	Apr. 7	Dec. 7	245
1859...	Apr. 21	Nov. 30	224	Apr. 19	Nov. 29	225	Apr. 20	Dec. 7	232	Apr. 30	Dec. 5	220	Apr. 1	Dec. 8	252
1860...	Apr. 20	Dec. 5	230	Apr. 19	Dec. 3	229	Apr. 21	Dec. 10	234	Apr. 21	Dec. 10	234	Apr. 1	Dec. 6	250
1861...	Apr. 24	Dec. 4	225	Apr. 24	Dec. 3	224	Apr. 24	Dec. 12	233	Apr. 24	Dec. 10	231	Apr. 8	Dec. 12	249
1862...	May 4	Dec. 6	216	Apr. 30	Nov. 30	215	May 1	Dec. 12	226	Apr. 29	Nov. 30	216	Apr. 15	Dec. 15	244
1863...	May 4	Dec. 10	220	May 2	Dec. 4	217	May 4	Dec. 12	222	May 1	Dec. 7	221	Apr. 13	Dec. 13	244
1864...	Apr. 25	Dec. 10	229	Apr. 24	Dec. 3	224	Apr. 27	Dec. 10	227	Apr. 26	Dec. 10	229	Apr. 14	Dec. 11	242
1865...	May 1	Dec. 12	226	Apr. 25	Dec. 7	227	Apr. 26	Dec. 13	231	Apr. 29	Dec. 13	229	Apr. 17	Dec. 15	242
1866...	May 2	Dec. 13	226	Apr. 30	Dec. 8	223	Apr. 30	Dec. 13	227	May 1	Dec. 11	225	Apr. 17	Dec. 11	238
1867...	May 1	Dec. 2	216	Apr. 29	Dec. 2	218	May 1	Dec. 1	215	May 1	Dec. 6	220	Apr. 23	Dec. 7	229
1868...	Apr. 27	Dec. 5	223	Apr. 27	Dec. 2	220	Apr. 27	Dec. 8	226	Apr. 26	Dec. 5	224	Apr. 15	Dec. 9	239
1869...	May 3	Dec. 7	218	May 3	Nov. 30	211	May 3	Dec. 7	218	May 1	Dec. 3	216	Apr. 21	Dec. 10	233
1870...	Apr. 29	Dec. 10	225	Apr. 28	Dec. 5	221	Apr. 28	Dec. 8	224	Apr. 23	Dec. 10	231	Apr. 6	Dec. 16	240
1871...	Apr. 21	Dec. 6	226	Apr. 19	Dec. 2	227	Apr. 20	Dec. 8	232	Apr. 21	Dec. 6	229	Apr. 20	Dec. 9	247
1872...	May 5	Dec. 4	218	May 1	Dec. 2	216	May 2	Dec. 8	221	May 1	Dec. 7	221	Apr. 22	Dec. 10	233
1873...	May 9	Nov. 24	209	May 1	Nov. 24	208	May 1	Dec. 4	218	May 1	Dec. 2	216	Apr. 21	Dec. 15	239
1874...	Apr. 21	Dec. 4	228	May 3	Nov. 25	207	Apr. 29	Dec. 4	220	May 1	Dec. 5	219	Apr. 9	Dec. 10	246
1875...	May 1	Dec. 1	215	May 3	Dec. 1	213	May 4	Dec. 6	217	May 4	Dec. 2	213	May 3	Dec. 14	226
1876...	May 1	Dec. 2	216	May 1	Dec. 8	222	May 1	Dec. 8	222	May 1	Dec. 4	218	Apr. 17	Dec. 11	239
1877...	May 7	Dec. 1	209	May 6	Dec. 6	215	Apr. 26	Dec. 8	227	May 1	Dec. 7	221	Apr. 17	Dec. 5	234
1878...	May 8	Dec. 5	212	Apr. 24	Dec. 6	227	Apr. 22	Dec. 8	231	Apr. 29	Dec. 12	228	May 9	Dec. 14	220
1879...	May 4	Dec. 4	215	May 1	Dec. 2	216	May 2	Dec. 9	222	Apr. 28	Dec. 9	226	May 5	Dec. 5	215
1880...	Apr. 25	Nov. 27	217	Apr. 20	Nov. 28	223	Apr. 26	Dec. 6	225	Apr. 20	Dec. 11	236	May 1	Nov. 30	214
1881...	May 1	Dec. 1	215	Apr. 25	Nov. 28	218	Apr. 26	Dec. 10	229	Apr. 27	Dec. 10	228	May 2	Dec. 15	228
1882...	Apr. 25	Dec. 1	221	Apr. 25	Dec. 1	221	Apr. 25	Dec. 6	226	Apr. 24	Dec. 11	232	Apr. 20	Dec. 5	230

METEOROLOGY OF CANADA

MEAN MONTHLY TEMPERATURES IN THE SEVERAL PROVINCES, AND AT CERTAIN PLACES, FROM MANY YEARS' OBSERVATION.

Provinces.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Newfoundland ...	25·6	22·7	28·7	33·3	43·0	50·7	60·3	60·1	55·8	49·6	38·0	28·9	41·4
Prince Edward Island	20·5	14·7	27·6	33·1	46·2	54·0	64·3	62·7	57·2	49·4	32·7	22·9	40·5
Nova Scotia	22·3	21·2	26·7	35·9	44·6	56·6	63·3	62·9	56·4	48·2	36·5	25·5	41·7
New Brunswick ...	16·1	18·1	26·4	37·6	46·4	57·7	62·8	61·4	54·2	45·1	32·3	19·8	39·9
Quebec	13·5	15·9	25·3	41·8	54·9	66·0	70·2	68·1	58·7	47·0	33·1	17·1	42·6
Ontario	19·3	20·2	26·7	42·6	54·4	65·6	69·8	68·1	58·6	47·4	33·0	20·5	43·8
Manitoba	3·9	3·0	9·0	30·2	51·2	63·6	65·9	64·8	51·3	40·0	14·6	0·6	32·6
British Columbia...	2·8	28·8	40·8	51·9	59·9	64·5	72·2	70·7	61·4	49·3	30·0	24·5	48·1
Places.	°	°	°	°	°	°	°	°	°	°	°	°	°
Halifax	22·9	23·7	28·1	38·1	47·4	59·7	63·5	63·3	57·4	48·3	37·8	25·8	43·1
St. John, N.B. ...	18·4	21·4	27·8	38·[illegible]	46·7	54·7	59·7	59·5	54·5	45·6	35·7	22·8	40·3
Montreal	16·8	18·6	26·9	43·5	57·2	66·4	72·2	69·8	60·8	47·5	33·6	18·9	44·3
Toronto	22·9	22·9	29·3	41·0	51·7	61·7	67·4	66·2	58·1	45·9	36·2	25·7	44·1

AVERAGE HIGHEST MONTHLY TEMPERATURES FOR VARIOUS PLACES FROM THREE OR MORE YEARS' OBSERVATIONS.

Places.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Year.
Ontario.	°	°	°	°	°	°	°	°	°	°	°	°	°
Toronto	43·9	44·4	51·9	67·2	76·2	86·1	89·2	86·0	81·2	68·6	56·9	47·3	91·1
Goderich	45·1	46·2	52·8	72·8	78·5	86·6	87·0	86·2	81·2	72·3	57·2	44·6	89·1
Woodstock	47·3	51·2	52·0	77·5	85·5	89·6	89·6	90·9	85·6	73·1	50·9	41·2	92·8
Peterborough	43·3	45·8	50·5	72·3	83·2	90·5	92·2	91·3	86·8	73·6	56·8	43·9	94·2
Pembroke	40·9	44·9	55·8	68·9	87·4	93·9	93·8	88·7	84·2	75·4	57·3	40·7	95·1
Quebec.													
Montreal	[illegible]	43·3	52·8	73·8	87·1	89·9	92·3	90·1	84·1	79·9	58·8	44·6	96·1
Quebec	38·2	37·6	43·7	61·4	81·9	90·2	89·6	82·5	78·9	69·2	46·4	38·8	90·6
New Brunswick.													
St. John	40·8	41·0	45·8	56·8	67·2	75·4	78·[illegible]	76·2	70·6	60·6	54·2	44·6	79·0
Bass River	42·0	39·9	48·0	56·1	77·8	88·0	87·1	85·1	78·5	69·4	56·9	41·3	88·6
Nova Scotia.													
Halifax	47·4	45·7	52·1	63·6	78·9	83·2	86·1	86·4	81·0	72·4	59·1	48·3	88·3
Sydney	48·7	43·3	49·2	57·2	75·4	79·5	83·4	84·0	75·0	69·2	56·9	48·1	85·6
Prince Edward Island													
Charlottetown	48·8	41·8	49·1	52·6	74·7	78·8	87·0	82·3	73·8	68·6	55·0	45·0	87·0
Manitoba.													
Winnipeg	27·5	36·6	38·6	64·3	82·8	91·6	95·2	92·3	84·8	72·4	43·4	30·0	96·1
British Columbia.													
Spence's Bridge, on the Thompson River	47·7	51·3	67·7	80·7	87·4	87·7	96·7	93·7	87·3	77·7	57·7	45·3	96·7

AVERAGE LOWEST MONTHLY TEMPERATURES FOR VARIOUS PLACES FROM THREE OR MORE YEARS' OBSERVATIONS.

Places.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Year.
Ontario.	°	°	°	°	°	°	°	°	°	°	°	°	°
Toronto	- 7·1	- 7·4	2·4	19·2	30·6	38·3	46·4	44·4	34·3	24·9	14·8	- 2·7	- 12·1
Goderich	- 1·3	- 1·1	2·1	21·6	28·4	39·1	46·4	44·5	36·3	28·8	13·9	- 2·9	- 8·8
Woodstock	- 7·6	- 13·0	5·2	22·2	28·5	36·0	42·2	44·1	29·6	20·2	1·1	- 15·5	- 18·2
Peterborough	- 20·7	- 15·5	- 11·1	16·3	27·1	36·7	43·2	36·7	28·2	16·3	1·0	- 22·8	- 25·9
Pembroke	- 32·7	- 26·5	- 23·2	11·0	26·8	36·1	44·4	37·8	30·0	20·3	0·0	- 26·8	- 37·3
Quebec.													
Montreal	- 18·2	- 12·2	- 9·5	27·4	37·2	49·7	53·4	52·0	41·2	28·9	- 3·5	- 12·3	- 17·2
Quebec	- 20·3	- 17·8	- 8·9	17·5	30·9	42·2	46·6	45·5	36·4	25·6	3·4	- 16·8	- 23·5
New Brunswick.													
St. John	- 11·0	- 6·4	- 1·2	20·2	31·8	43·0	49·0	48·4	41·0	25·0	12·8	- 5·8	- 10·6
Bass River	- 20·2	- 15·2	- 3·4	17·4	25·4	40·0	47·8	41·6	33·7	20·0	7·0	- 12·5	- 22·6
Nova Scotia.													
Halifax	- 6·2	- 3·0	- 0·7	19·8	25·8	37·6	50·2	44·3	36·5	25·7	16·7	1·9	- 8·8
Sydney	- 6·3	- 5·3	- 4·3	14·7	25·0	32·3	38·3	41·4	33·6	24·7	19·7	- 5·1	- 9·8
Prince Edward Island.													
Charlottetown	- 15·0	- 15·7	- 2·0	14·7	27·7	36·6	44·9	45·1	39·4	32·2	13·7	- 8·7	- 16·5
Manitoba.													
Winnipeg	- 35·9	- 33·2	- 29·3	1·0	25·4	38·1	41·2	40·4	26·1	8·1	- 28·8	- 34·2	- 38·6
British Columbia.													
Spence's Bridge	- 7·7	- 5·3	16·5	31·7	39·4	47·0	53·0	49·7	36·3	27·0	2·3	- 2·7	- 16·7

MEAN MONTHLY RAINFALL IN INCHES FOR VARIOUS PLACES FROM THREE OR MORE YEARS' OBSERVATIONS.

	Places.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Ontario.	Toronto	1.23	0·89	1·62	2·44	3·25	2·98	3·25	3·02	3·72	2·39	2·98	1·65	29·42
	Goderich	0.66	0·55	1·39	1·81	3·38	2·39	2·94	2·78	3·28	2·46	1·44	0·84	23·92
	Woodstock	0·59	0·58	1·31	1·60	3·04	2·45	2·96	4·41	2·93	2·64	0·95	0·82	24·28
	Peterborough	0·64	0·36	1·01	1·89	1·96	2·03	2·45	2·60	3·22	2·93	1·81	0·65	2·055
	Pembroke	0·15	0·15	0·56	1·33	3·06	2·28	2·51	2·36	3·21	2·58	1·09	0·21	19·49
	Montreal	0·64	0·42	1·41	1·30	2·26	3·01	2·26	3·62	3·9	3·75	2·66	0·85	27·26
	Quebec	0·25	0·00	0·42	1·17	2·52	1·11	2·52	4·27	2·81	2·89	0·95	0·00	19·26
	St. John	2·13	2·86	2·23	3·14	4·51	3·00	3·45	3·89	4·38	4·68	5·33	2·67	33·27
	Bass River	1·30	0·61	0·92	2·13	2·83	3·30	2·53	3·77	2·58	4·88	3·78	1·15	29·78
	Halifax	3·66	3·39	2·91	3·10	4·17	3·04	2·37	3·61	3·69	5·02	4·68	3·44	43·08
	Sydney	3·49	3·16	2·20	4·03	3·46	3·16	3·42	5·07	5·48	5·04	6·88	4·03	49·42
	Charlottetown	2·27	0·68	1·12	0·97	2·44	3·79	2·92	3·48	3·94	4·62	2·46	1·06	29·75
	Winnipeg	0·00	0·00	0·33	0·80	2·72	3·84	2·75	2·12	3·73	0·54	0·00	0·00	16·83
	Spence's Bridge	0·08	0·19	0·00	0·21	0·78	0·81	0·25	0·47	0·32	0·20	0·37	0·20	3·88

AVERAGE FALL OF SNOW IN THE SEVERAL PROVINCES WITH THE NUMBER OF DAYS OF SNOW, AND OF RAIN.

PROVINCES.	Depth of Snow in inches.									Total Snow of the Season.	Number of Days' Snow.	Number of Days' Rain.
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.			
Prince Edward Island	...	...	12·5	26·9	15·6	22·1	17·6	17·2	0·5	112·4	78	129
Nova Scotia	...	0·8	4·0	21·9	17·6	18·9	11·8	13·3	1·1	92·4	52	117
New Brunswick	...	1·3	10·1	31·9	19·2	19·6	15·3	10·2	0·8	108·4	58	107
Quebec	...	2·0	13·9	23·2	31·8	16·4	17·5	8·8	1·4	115·0	60	94
Ontario	...	2·2	13·5	20·1	25·1	14·9	19·9	2·2	S	95·9	58	89
Manitoba	3·1	4·8	11·6	8·9	7·4	13·4	9·7	3·6	0·0	62·5	59	62
British Columbia	...	...	6·0	8·7	10·0	5·5	3·3	S	0·0	33·5	27	66

DURATION OF WINTER AT MONTREAL AND TORONTO, FROM TWENTY-SIX YEARS' OBSERVATIONS.

Year.	MONTREAL. First Snow.	MONTREAL. First Frost.	MONTREAL. Last Snow.	MONTREAL. Ice left River.	TORONTO. First Snow.	TORONTO. First Frost.	TORONTO. Last Snow.	TORONTO. Ice left Bay.
1849	November 27	October 5	April 13	April 7	October 20	September —	April 27	March 29
1850	„ 17	„ 14	„ 14	„ 9	November 10	„ —	„ 20	April 3
1851	October 25	„ 2	„ 8	„ 9	October 24	„ —	May 8	March 24
1852	„ 17	September 17	„ 16	„ 19	November 11	September 13	„ 20	April 17
1853	„ 24	„ 12	„ 14	„ 24	October 25	„ 12	„ 10	March 31
1854	„ 15	„ 11	„ 30	„ 25	„ 16	„ 19	April 29	April 8
1855	„ 24	August 9	„ 11	„ 28	„ 12	„ 28	May 8	„ 16
1856	November 1	„ 26	May 31	„ 24	„ 30	„ 22	„ 30	„ 19
1857	October 20	September 7	April 27	„ 18	„ 28	„ 21	„ 10	March 30
1858	November 4	August 25	„ 22	„ 9	„ 8	„ 18	April 25	„ 27
1859	October 20	October 7	„ 23	„ 4	„ 19	„ 6	June 4	June 27
1860	September 29	September 3	May 20	„ 10	September 25	„ 21	April 25	March 15
1861	October 23	„ 5	April 17	„ 24	October 24	„ 22	May 6	„ 29
1862	November 10	August 24	May 7	„ 23	„ 25	August 30	April 23	Feb. 28
1863	„ 11	October 24	„ 2	„ 25	November 8	„ 26	May 5	„ 14
1864	October 8	September 26	April 18	„ 13	October 8	September 17	April 13	March 2
1865	„ 28	October 21	„ 20	„ 10	„ 26	„ 12	„ 23	April 1
1866	„ 4	September 16	May 3	„ 19	„ 31	„ 15	„ 26	„ 2
1867	November 5	„ 23	„ 2	„ 22	November 4	„ 11	May 2	March 27
1868	October 17	October 24	April 23	„ 17	October 16	„ 17	April 23	April 1
1869	September 27	September 28	May 3	„ 23	„ 18	August 31	May 1	„ 1
1870	October 29	„ 6	April 5	„ 18	November 10	„ 27	April 5	„ 1
1871	„ 18	„ 8	March 27	„ 8	October 17	September 18	„ 12	March 13
1872	„ 11	October 12	April 24	not given	„ 15	„ 3	„ 23	April 9
1873	„ 29	„ 29	May 14	„	„ 20	„ 15	„ 25	„ 2
1874	„ 31	„ 13	„ 2	„	„ 13	„ 30	„ 26	„ 18

Temperature, Humidity, and Precipitation, at Montreal.

From the Record of the McGill College Observatory,—C. H. McLeod, *Superintendent.*

Month.	(Saturation 100.) RELATIVE HUMIDITY.						
	1875.	1876.	1877.	1878.	1879.	1880.	Mean for the Month.
January	81	78	79	81	82	78	79·8
February	78	77	78	72	75	74	75·7
March	76	77	76	72	82	69	75·3
April	67	68	62	79	62	69	67·8
May	69	70	60	70	62	64	65·8
June	72	73	67	64	74	67	69·5
July	75	73	68	62	71	67	69·3
August	77	69	76	75	70	68	72·5
September	76	81	71	75	74	74	75·2
October	80	79	78	78	71	78	77·3
November	80	83	84	82	79	79	81·2
December	84	82	82	80	80	82	81·7
Yearly Means.	76·4	75·9	73·4	74·2	73·5	72·5	74·3

Table showing the Number of Days on which the Mean Temperature has been below Zero, 30°, 40°, &c., at Montreal.

Year.	At and below Zero.	At and below 32°.	At and below 40°.	At and below 50°.	At and below 60°.	At and below 70°.	At and below 80°.	At and below 90°.
1875......	23	145	186	239	262	336	365	365
1876......	11	118	181	228	275	317	362	366
1877......	7	110	163	208	249	320	365	365
1878......	5	95	156	190	253	330	362	365
1879......	9	137	164	198	264	342	365	365
1880......	12	130	173	206	252	307	366	366
Means ...	11	122	170	211	259	325	364	365

The mean temp. of the air during Nov. Dec. Jan. Feb. & Mar. (1875 to 1880) was 21°·1
,, max. ,, ,, ,, ,, ,, ,, 59·5
,, min. ,, ,, ,, ,, ,, ,, 25·2
,, mean ,, ,, April, May, and October, ,, ,, 74·4
,, max. ,, ,, ,, ,, ,, ,, 85·6
,, min. ,, ,, ,, ,, ,, ,, 8·5
,, mean ,, ,, June, July, Aug. and Sept. ,, ,, 64·4
,, max. ,, ,, ,, ,, ,, ,, 92·2
,, min. ,, ,, ,, ,, ,, ,, 33·1

Rainfall in Inches at Montreal.

Month.	1875.	1876.	1877.	1878.	1879.	1880.	Mean of Six Years.
January ...	0·00	1·87	0·12	0·40	0·00	1·27	0·16
February ...	0·42	1·12	0·34	0·28	0·03	1·14	0·55
March	0·80	0·74	2·73	0·58	1·23	0·04	1·02
April	1·18	1·03	1·98	3·55	0·27	3·17	1·86
May	5·13	3·45	0·62	4·11	0·80	2·97	2·85
June	3·26	3·21	2·35	1·18	4·82	3·27	3·01
July	3·64	4·33	3·65	5·47	4·79	5·35	4·54
August	2·59	1·98	3·50	3·95	1·40	1·44	2·48
September ...	5·13	5·51	1·50	1·59	3·18	2·83	3·30
October ...	4·74	2·64	3·19	5·39	1·70	4·44	3·60
November ...	0·50	1·76	4·31	3·47	2·81	3·63	2·75
December ...	0·68	0·00	1·17	2·70	1·74	0·29	1·10
Means & Sums	28·12	27·64	25·46	32·67	22·77	29·84	27·75

Snowfall in Inches at Montreal.

Month.	1875.	1876.	1877.	1878.	1879.	1880.	Mean of Six Years.
January ...	35·0	27·4	23·3	30·5	39·5	16·3	28·7
February ...	12·9	27·5	3·6	10·2	27·4	26·0	17·9
March	14.6	45·6	22·4	19·4	32·6	25·1	26·6
April	7·3	12·0	10·2	2·3	6·9	8·6	7·9
May	0·0	0·3	0·0	1·0	0·0	0·0	0·2
June							
July							
August							
September ...							
October ...	0·0	1·0	5·4	0·1	0·0	3·1	1·6
November ...	21.7	0·7	5·1	14·6	16·8	12·7	11·9
December ...	24·2	2·36	4·3	32·8	37·4	17·6	23·3
Means & Sums	115·7	138·1	74.3	110·9	160·6	109·4	118·2

Note.—The depth of melted snow is taken at one-tenth the snowfall.

CHAPTER III.

EGYPT.

AREA AND POPULATION.

RIVER BASINS AND RIVERS.

CANALS AND IRRIGATION.

IRRIGATED CROPS.

METEOROLOGY.

EGYPT.—AREA AND POPULATION ACCORDING TO

Mudiriah.	Districts.	Towns.	Villages.	In 1872. Area irrigated. Feddans or Acres. †
Upper Egypt—1. Esnah	3	2	87	131 740
2. Kenekossir	4	5	102	263 023
3. Girgah...	4	4	188	330 176
4. Assiut	5	4	281	421 102
	16	15	658	1 146 041
Middle Egypt—1. Miniah and Benimazar	4	2	259	392 778
2. Benisuef	3	3	69	228 782
3. Fayum	3	1	86	206 056
	10	6	414	827 616
Lower Egypt.—1. Gizah	3	3	160	170 943
E. 2. Galliubiah	3	3	159	181 115
E. 3. Sharkiah	5	11	429	404 493
E. 4. Dahkaliah	4	4	437	429 636
C. 5. Manufiah	5	13	331	352 253
C. 6. Garbiah	10	36	484	747 883
W. 7. Behera...	5	22	253	364 240
	35	92	2253	2 650 563
Rural Egypt	61	113	3 325	4 624 220

Large Towns.—Cairo ... ...
Alexandria ... ...
Damiat .. ..
Rashid ... ...
Suez ... ...
Port Said ... ...
Ismailiah ... ...

Urban Population ... ...

All Egypt ... ...

† The feddan used in these

OFFICIAL RETURNS IN 1872 AND 1882.

Rural Egyptian Population, 11 March, 1872.	Migratory Arabs in 1871.	Population in 1882.
251 742	19 470	182 200
297 614	70	256 195
378 237	—	322 920
433 111	—	582 435
1 360 704	19 540	1 343 750
325 096	2 500	344 775
125 511	—	176 015
154 167	5 896	202 510
604 774	8 396	723 300
153 745		245 835
190 964	2 000	240 255
401 287	—	400 030
500 304	220	414 275
447 917	70	505 315
629 763	—	686 610
213 556	9 000	259 685
2 537 536	11 290	2 752 005
4 503 014	39 226	4 819 055
Egyptians in 1872.	Europeans in 1871 ?	
333 780	19 120	446 144
164 718	47 316	227 040
29 333	50	29 665
14 992	10	13 870
11 098	2 400	9 715
4 461	4 210	15 510
4 236	1 110	8 421
562 618	74 216	750 365
5 065 632	113 442	5 569 420

tables is an English acre.

EGYPT.

RIVER BASIN.

The following are the main divisions of the Nile basin :—

		Square Miles.
I.	Lake Catchments, and Lake Surfaces	205 781
II.	Elevated Tablelands	282 308
III.	Plains South of Khartum	505 427
V.	The Nile Valley North of Khartum	175 116
	Total ...	1 168 632

These four main divisions may be thus sub-divided in accordance with meteorologic conditions :—

		Square Miles.
I.	LAKE SERIES :—	
1	The lake surfaces of Nyanza, Baringo and Lutanzige ...	44 593
2	Their catchments, mostly in plains	161 188
II.	TABLE LANDS :—	
1	The elevated Table-lands of the Sobat Basin	70 382
2	Those of the Yabus and Gojeb Basins	85 785
3	Those of the Abai or Middle Abyssinia	92 424
4	Those of the Takazza in Northern Abyssinia	33 714
III.	SOUTHERN PLAINS :—	
1	Plains and Hills of Darfur	139 081
2	Those of the Basin of the Ghazal	161 897
3	Betwen the White Nile and the Sobat—long strip ...	86 453
4	Between the White and Blue Niles	54 087
5	Plains right bank of Blue Nile	63 909
IV.	THE NILE VALLEY BELOW KHARTUM :—	
1	Valley from Khartum to Takazza confluence	44 428
2	" Takazza confluence to Cairo	122 082
3	Surface of the Delta	8 606

Navigability of the Nile in Nubia and Dongola.

From Khartum downwards.

		Miles.
Khartum to Shendy	navigable	114
Shendy to El Kab	3 cataracts	267
El Kab to Umderas	continuous rapids	22
Umderas to Gerindid	7 cataracts	50
Gerindid to Dalah	cataracts	367
Dalah to Wadi Halfa	9 cataracts	86
Wadi Halfa to Philœ	navigable	249
Philœ to Assuan	1 cataract	7
		1 162
Assuan to Esnah	navigable	99
Esnah to Siyut	navigable	231
		330

NOTE.—The official reductions are full of mistakes.

Lengths and Surfaces of the Nile in Egypt.

From Assuan downwards.

	Mudiriahs.	Length, in feet.	Average Width, in feet.	Surface, in acres.
Upper Egypt.	1. Esnah	744 000	2 400 to 3 000	48 673
	2. Kenah	540 000	2 400	29 754
	3. Girgah	450 696	3 900 to 4 320	42 519
	4. Siyut	432 000	3 000 to 4 200	46 579
Middle Egypt.	1. Miniah and Beni-mazar	422 520	2 700	26 190
	2. Benisuef	288 000	6 000 to 7 200	41 158
Lower Egypt.	1. Gizah	387 132	2 400 to 3 000	26 468
		3 264 348	—	261 341
	Dam to Damiad ...	744 000	720 to 2 484	31 647
	Dam to Rashid	738 492	1 440 to 2 160	31 233
		1 482 492	—	62 880
	Total, with branches ...	4 746 840	—	324 221

The altitudes along the course of the river are these :—

Altitudes, in feet.		Distances, in miles.	Falls, in feet.	Mean Slopes. S. per 1000.
	On the White Nile.			
3553·	Lake Nyanza to Karuma	... 186·	304·	
3249·	Karuma to Lake Lutanzige	... 106·	912·	rapids
3337·	Lake Lutanzige to Galuffih	... 112·	88·	0·1500
2249·	Galuffih to Gondokoro	... 149·	230·	cataracts.
2019·	Gondokoro to Lake Noo	... 615·	295·5	0·0900
1723·5	Lake Noo to Khartum	... 777·	410·	0·1000
		1945·	2239·5	
	On the Blue Nile.			
1667·5	Fazokl to Khartum ...	... 466·	354·	0·1500
	On the Main River.			
1313·5	Khartum to Assuan ...	...1181·	984·5	0·1580
329·0	Assuan to Cairo	... 622·	285·5	0·0870
43·5	Cairo to sea at low water	... 120·	43·5	0·0687
		1923·	1313·5	

RIVERS.

The Nile.—The generally correct knowledge of the hydrology of this river seems to have been first diffused by the experienced Lombardini in 1864, after the explorations of Burton, Speke, Grant, and Baker, and subsequent to the observations of Klöden, Linant, Penny, and Petherick. His account is hence the basis from which more recent observers diverge.

Climatology.—Collecting the then available climatic data for the catchments of the Nile, that were used by him :—

I. Near Lake Nyanza, in 1862 the observations of the expedition gave 240 rainy days in the year, with tolerably equable distribution of 4·345 feet of rainfall; two rainy seasons, one for three months from March to May, giving 1·398 feet of rainfall, the other for two months, October and November, giving 1·250 feet. The mean monthly temperature was 70° F.; the lowest minimum monthly 53° in December, and the highest monthly 88° in August (Galton Proc. Geogr. Soc., 1853).

II. To the table-lands of Abyssinia the rain is brought from the Indian Ocean by the E. and S.E. winds, and the humidity of the air is excessive; the rainy season, or Kharif, is the winter. The rainfall at Intetshao (lat. 14° 17′) in 1841 was

during April, May, and June 0·583 feet; during July, August, and September 1·986 feet; in all 2·569 feet. In the mountains, rain or snow falls throughout the year at intervals, but the winter snow falls on them before the vernal equinox. The temperature in the Kollas 4 600 to 6 500 feet above mean sea level, varies from 77° F. to 98°; in the Vainadegas, altitude 6 500 to 8 500, it is between 57° and 80°; in the Degas, altitude 8 500 to 9 800, it is between 32° and 62° F.

III. As to the Southern Plain catchments. First, for Darfur little or no information is available; but for Kordofan, there is solely the small amount gleaned at El Obed (lat. 13° 5′), by Kinzelbach in 1862, that no rain fell before 22nd June, and that the temperature in May varied from 86° to 99° F. In the Ghazal Basin, the observations of Brun-Rollet in 1856, at lat. 9° 16′, near its confluence with the Nile, shows three falls of rain in April, eleven in May, four in the first ten days of June, after which they probably continue till September; the temperature varied between 77° and 102° F.

For the plains between the White Nile, or Kir, and the Sobat, there are some observations taken at Gondokoro, lat. 5°, by Dovyak in 1853. The periodical intertropical rains prevail throughout the whole year in the regions from the Equator northward. There are two rainy seasons at Gondokoro, one from February to May, in which there were 44 rainy days; the other lasting during August only, in which there were 12 rainy days, the rest of the year giving only 31. The amount of fall was not recorded; but the mean yearly temperature was about 83° F., while that for from June to November was only 79°.

For the plains between the White and Blue Niles, there were observations made in Sennaar, between lat. 15° and 11°, in 1860. The rains there commence in May and end in October, the fall occurs generally at night, and they are of a stormy sort; the heat is excessive after rain.

At Khartum, the observations of Dovyak in 1852 gave 21 rainy and 12 cloudy days out of 144; there is rarely rain in May and June, the annual rain falling between July and October. The mean day temperature in the shade was 90°, the extremes being 83° and 94°.

For the plains on the right bank of the Blue Nile there is no climatic information beyond that given generally for Sennaar.

IV. For the conditions of the Nile Valley—from Khartum

to Assuan, the valley is generally nearly rainless. In Middle Egypt, from Assuan to Siyut, the rainfall is exceedingly small, the mean temperature is from 93° to 101°, but on one or two occasions ice has been seen in January. At Cairo, the average number of rainy days is 7, giving a fall of 0·10 foot; the mean of the annual maximum temperature is 72° F.; the mean monthly temperature varies from 55° in January and February to 86° in July and August.

At Alexandria, there are 40 showery days on an average. At Port Said, in 1863, the total annual rainfall was only 0·53 foot.

Water Levels and Discharges.—It seems that the variations in the water level of Lake Nyanza, as well as those of the other two equatorial lakes, are now small both annually and from year to year; also that the discharges from them are now comparatively insignificant. If such be the case, the balance of rainfall and evaporation must on the whole be very even, and the data of supply may be roughly these:—

Supply from Lake Catchments.		Cubic feet per second.
4·4063 feet of rainfall in a year.		
3·9371 " evaporated "		
0·4692 feet drained from 161 188 square miles	=	57 707
Supply from Lake Surfaces.		
2·9528 feet of rainfall in a year.		
3·9371 " evaporated "		
0·9843 feet of loss, from 44 593 square miles	=	33 492
Rate of annual discharge	=	24 215

If this be divided in the ratio of the three lake-surfaces, it gives only 2 421 cubic feet per second as due to Lake Baringo, the rest to the other two.

We may assume from the observations of the explorers that the whole of this efflux passes eventually into the White Nile; that from Lake Baringo passing into it through the Assua at Galuffih.

The above quantities are in accordance with the observed low water discharge at Khartum after the reception of more supply from other streams. They also agree with the account given by Speke of the channels leading out of the lakes; the chief one from Lake Nyanza having a breadth of 443 feet and a current of 6 feet per second. At or near Gondokoro, the Kir, or White

Nile, was 656 feet wide, and from 5·9 to 8·6 feet deep according to Knoblecher (Klöden); also at a point one degree below it he gives the current at 3·28 feet per second. Taking the average depth at 7·22 and the section at 4 736 square feet, the current at 4·1 feet per second at Gondokoro, the discharge there would be about 19 424 cubic feet per second.

There would thus be a loss of about 5 000 cubic feet per second, between the lakes and Gondokoro, which may be accounted for by some escape into the Jeji, and other overflow to waste.

Dovyak, who was at Gondokoro in 1853 and 1854, relates that the Kir begins to rise in May, and during May and June the rise oscillates between 2 and 3 feet above zero. In July the rise is 4½ feet; in September, the greatest rise on the 4th September was 6½ feet, and the water fell in the same month to 4 feet. In October the rise was between 3 and 4½ feet above zero; this remained during November and December. On the 20th January, 1854, the water fell to 3 feet, but in January, 1853, it had fallen to 0·16 foot below zero. Noticing that the before-mentioned discharge of 19 424 cubic feet per second was at low water, and at this zero; the high flood of 4th September, 1853, would be about 50 504 cubic feet per second, or even as much as 56 507, bearing a torrential nature, while the mean flood or high water stage of December, amounting to 31 785 cubic feet per second, was constant, and of lacustrine origin. In lat. 6°, or one degree below Gondokoro, the Kir begins to take a marshy character, which continues until it joins the River Ghazal at Lake Noo: the whole of this territory is a swamp divided by many channels. At 1° below Gondokoro, Harnier, in 1861, described the Kir as rising suddenly on 17th April for several feet, and falling suddenly the next day. The waters were discoloured and reddish, as in the flooded Nile in Egypt. On 11th May, after some days' moderate rain, there was a violent storm and very high torrential flood. June was rainless, but storms occurred in the middle of July. The river continued to rise till the end of September, an exceptional case, and did not begin to fall till the 20th October.

At a mile below the Makedo Rapid, a place 80 miles from that of Harnier's observations, Dr. Penny, in (July ?) 1861, found the average depth of the Kir to be 17·6 feet, the width 147·6 feet, and the greatest velocity in the section 9·84 feet per second.

Applying a coefficient of 0·80 to deduce a mean velocity,

the discharge would be 19 848 cubic feet per second; thus agreeing with the result due to the observations of Knoblecher. He also mentions that the low-water state of the Kir in February and March is permanent, excepting a flood of a few hours on 13th February rising 2 feet.

As to the region west of the Kir, and the Upper Ghazal, very little is known, in spite of the attempts of Petherick, Poncet, Brun-Rollet, and Morlang. After 1864, Petherick made some results known, which do not affect the discharge materially.

The vast region watered by the River Ghazal and its affluents, above Lake Noo, is also little known, its marshy nature rendering hydraulic observations difficult. The rainy season there commences in May, and the rains are strongest in July; but the discharge from the Ghazal commences only in June; thus the marshes detain all rainfall for at least a month. Heuglin measured the mouth of the Ghazal in February, 1863: it was 1 050 feet wide, with an extreme depth of 13 to 20 feet, but with low banks submerged to great depth in high flood.

Below Lake Noo, the Keila River after a long course, from Darfur, is joined by the Chidi or Shelengo from Darfertit, and the combined marshy stream joins the Abiyad or White Nile; its water-levels and discharges are unknown.

The Zharaf, an affluent on the right bank, also marshy, is perhaps an overflow from the Kir. Its discharge is unknown.

The Sobat, another affluent on the right bank, is a large river, but of very small depth in the dry reason, hence torrential by nature. Its mouth, according to Heuglin (1862–63), was 525 feet wide, with lofty banks of clayey soil that are just submerged in high flood.

According to Knoblecher its width was 635 feet; and from its conditions its probable high flood discharge may be 7 063, or even 8 476 cubic feet per second.

Below this confluence the White Nile here called the Abiyad, receives no important branch above Khartum.

The floods of the Kir arriving at Gondokoro in May, and leaving the Ghazal in June, would naturally not arrive at Khartum until July.

At Khartum as well as at Cairo there is a daily gauge record.

Noticing the observations of Linant Bey in 1849, near Khartum, which gave

	At Low Water.	At High Water.	
For the White Nile	10 489	213 455	Cubic ft. per second.
For the Blue Nile ...	5 615	220 629	"
For the combined streams	—	423 730	"
Difference from sum	—	10 354	"

Lombardini divides the difference proportionately between the two streams, to correct the separate discharges at high water, making them 208 545 and 215 575 cubic feet per second.

For the discharge of the Takazza, about 186 miles below Khartum, Lombardini calculates it roughly from the catchment to be about 1 555 cubic feet per second at low water, and 54 812 cubic feet per second at high water. Adding these discharges respectively, to obtain Nile discharges below the Takazza, Lombardini constructs from them a sectional discharge-formula for various heights of water level above datum. The datum is set at 6·234 feet below low-water level.

$$Q = 3310{\cdot}2\,(H - 3{\cdot}1825)^{\frac{3}{2}}$$

This formula gives—

	H. Height in feet.	Q. Cub. ft. per second.
For low water	6·234	17 645
For ordinary flood	30·578	474 650

The curves of the annual gauged levels for Khartum are generally unbroken rises and falls of great regularity, owing to the large marshes on the White Nile.

At Monfalut below Siyut, Girard estimated the low-water discharge on 27th March, 1799, at 23 945 cubic feet per second, the section being 12 159 square feet, and the velocity of the thread of the current 2·4614 feet per second. His deductions of flood discharges are faulty, owing to assuming too great a hydraulic slope for them.

Lombardini assumes that the flood slopes are parallel to the low-water slopes. He estimated a low-water discharge and a mean flood discharge at Cairo, and constructed on that basis a sectional discharge-formula—

$$Q = 2056{\cdot}2\,(H - 2{\cdot}2966)^{\frac{3}{2}}$$

giving discharges Q corresponding to heights H, above datum. This datum is set at 6·004 feet below low-water level. This formula yields the following results, which accord with his observations :—

		Feet.		Cub. ft. per second.
At low water	H=	6·004	Q=	14 676
In ordinary flood		30·283		304 425
For high flood of 1800 ...		32·120		334 887

From such calculated data, in addition to the gauge records of a year, he obtains the annual discharges. (The gauge records have been kept at Cairo since 1799, and perhaps much longer.)

From the pair of hydrometric formulæ the annual discharges at Cairo and at the confluence of the Takazza in millions of cubic feet may be obtained with the help of the annual gauge records of water-level; but it is more convenient to use rates of discharge in cubic feet per second, at the distinctive periods. The Cairo discharges are taken out for the two years, 1799–1800 and 1800–1801, and the mean for the two years is used.

	Rates for Annual Discharge below the Takazza. Cubic feet per second.	Rates for Annual Discharge at Cairo. Cubic feet per second.
Low water	16 057	6 374
Rising flood	30 374	19 770
Highest flood	61 638	29 313
Falling flood	21 176	55 324
Annually ...	129 245	110 781

In comparing these two sets of discharges, it must be noticed that at the beginning of the rise of flood the interval of time between the two places is about two months, at the speed of 1·68 miles per hour; while at highest flood the interval is about one month, at the speed of 3·11 miles per hour; so that these two conditions are at Cairo nearer to each other.

The loss of water between the two places may also be thus estimated:—

	Cubic feet per second.
Loss by evaporation in these rivers from Khartum, at 11·483 feet annually, over 784 square miles	6 869
Losses by effiltration and evaporation in overflows above Assuan, at 3·281 feet annually, over 309 square miles	7 737
Losses by effiltration and evaporation in overflows in Egypt above Cairo, at 2·625 feet annually, over 966 sq. miles	1 935
Total loss annually at the rate of	16 541
Whereas the difference of annual discharges before given is	18 464

The inexactitude may be considered trivial, as the discharge at Cairo in 1800 was nearly double that in 1799, and the mean has been used; while the discharge used for Khartum is that of 1849. But if the same year had been adopted in both cases, the probability still exists of the error being increased.

Lombardini meets this difficulty by showing that there are losses not simply annual that may be taken into account. First, the filling of the river bed from low water to flood, is a volume 24·61 feet deep, 2 625 feet wide, and 1 803 miles long; or about 61 456 millions of cubic feet; second, the effiltration from overflows that return to the river after high flood, estimated at 23 309 millions; together 84 763 million cubic feet. The first volume is partly lost during the flow from Khartum to Cairo, over the period from low to high water; it is also partly recovered during the period from high to low water. The second volume, the loss in effiltration of overflows that actually do return to the river, is indeterminable, but of its existence there is ample proof furnished by the experiments of Girard, near Esneh. His borings there at a period of low water showed the following differences of water levels in the soil at various distances, and in the river-bed :—

	Difference.
At 3 938 feet from the river	11·16 feet
At 5 907 feet „ „	14·38 „
At 10 502 feet „ „	16·31 „

These are the first known data that establish the law of flow of underground water. They also indicate that some losses must result during the period of return of the water to the river. The amounts of loss thus indicated do not admit of simple determination in annual rates.

The following water-levels and rates of discharge on the first day of each month in a year, help to illustrate the conditions of flow of the Nile with reference to their separate datum levels :—

Here the datum level for Gondokoro is a mean bed-level: those for Khartum and Cairo are their respective low-water levels. Inexact or approximate data are bracketed.

On 1st of each month.	At Gondokoro. 1853-4.		At Khartum below the Takazza. 1849-50.		Near Cairo. 1849-50.	
	Feet.	C. ft. p. sec.	Feet.	C. ft. p. sec.	Feet.	C. ft. p. sec.
May ...	7·22	(19 424)	1·44	31 044	(2·49)	34 328
June ...	9·19	—	2·46	42 628	(1·57)	26 841
July ...	10·17	(31 785)	7·84	115 593	2·07	30 796
August ...	10·17	(31 785)	17·26	293 908	8·76	99 594
September ...	12·14	(50 504)	22·70	419 637	19·72	256 474
October ...	11·16	—	22·31	409 333	23·30	319 550
November ...	10·17	(31 785)	14·80	242 733	18·77	241 322
December ...	10·17	(31 785)	8·04	119 478	11·98	140 561
January ...	10·11	—	4·27	64 489	9·87	112 695
February ...	10·04	—	2·30	37 365	8·56	97 262
March ...	(7·22)	(19 424)	1·80	35 811	6·27	70 528
April ...	(7·22)	(19 424)	1·48	32 421	2·95	38 248

Although a compa.ison of the discharges below Khartum and at Cairo for the same complete year is impracticable, Lombardini compares the discharges of the former for a year from 1st May, 1849, to those of the latter for a year, from 1st July, 1849, taking the same four corresponding positions on the curves of discharge as in the former case.

Rates for Annual Discharge of the Nile.

	Below the Takazza. Cubic feet per second.	At the Delta-head Dam. Cubic feet per second.
Low water	11 407 ...	... 8 736
Rising flood	31 823 ...	... 14 702
Highest flood	59 758 ...	... 46 266
Falling flood	25 258 ...	... 38 393
Annually ...	128 246	108 097

In this case the losses, amounting to 20 149 cubic feet per second, are more than in the former case, and though there is a difference of 12 miles in length of river course, they show the need of the extra annual allowance before explained; by which Lombardini accounts for the difference of discharge below the Takazza at Khartum, and at Cairo.

Yearly Variation.—This variation is shown in the following table, giving 12 years' record of heights of water-level above low-water level at the Delta-head, that is, at the French Barrage. The actual discharges in cubic feet per second, due to these recorded heights H in feet, may be calculated by Lombardini's formula suited to this section and datum.

$$Q = 2276{\cdot}1\ (H + 3{\cdot}609)^{\frac{3}{2}}$$

The mean discharges tabulated, are those to the mean heights for the 12 years in each period of 10 or 11 days.

Heights of Water Level of the Nile at the Delta Head, above Low Water, in Feet.

Date.	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	1861	Mean.	Maximum.	Minimum.	Corresponding Mean Discharges. Cubic ft. per sec.
10 January ...	9·09	8·56	9·19	8·24	10·37	10·99	7·64	9·45	6·89	7·71	9·19	8·53	8·80	10·99	6·89	99 494
20 " ...	8·46	8·17	8·79	7·68	9·65	9·94	6·82	8·89	5·91	6·99	8·37	9·29	8·24	9·94	5·91	92 836
31 " ...	7·48	7·55	8·20	6·73	9·22	9·35	6·07	8·40	5·18	5·74	7·58	8·83	7·53	9·35	5·18	84 618
10 February ...	6·50	6·89	7·78	5·91	8·53	8·89	5·68	8·01	4·56	4·92	7·38	8·53	6·97	8·89	4·56	78 317
20 " ...	5·74	6·00	6·63	5·09	7·68	8·63	4·69	7·05	3·77	4·20	6·56	7·97	6·17	8·63	3·77	69 604
28 " ...	4·09	5·41	5·87	4·43	7·02	8·37	4·23	6·33	3·31	3·45	6·07	7·09	5·47	8·37	3·31	62 266
10 March ...	4·50	4·66	5·28	3·94	6·46	7·78	3·84	5·54	2·85	3·12	4·20	6·43	4·88	7·78	2·85	56 296
20 " ...	3·87	4·10	4·69	3·41	5·18	7·28	3·54	4·76	2·40	2·40	3·35	5·45	4·20	7·28	2·40	49 669
31 " ...	3·45	3·58	3·97	3·12	4·59	6·40	2·89	4·04	1·90	1·77	2·36	4·69	3·56	6·40	1·77	43 690
10 April ...	3·02	3·12	3·61	2·79	3·94	5·49	2·33	3·54	1·48	1·21	2·00	4·04	2·88	5·49	1·21	37 623
20 " ...	2·72	2·76	3·25	2·26	3·35	4·72	2·07	3·02	1·06	0·92	1·51	3·54	2·60	4·72	0·92	35 215
30 " ...	2·43	2·36	2·99	1·77	2·76	4·07	1·71	2·59	0·84	0·62	1·02	3·09	2·19	4·07	0·62	31 785
10 May ...	2·23	1·97	3·35	1·64	2·43	3·51	1·51	2·23	0·59	0·23	0·85	2·69	1·94	3·51	0·23	29 752
20 " ...	1·90	1·54	3·08	1·44	2·07	3·15	1·48	1·74	0·43	0·00	0·36	2·40	1·63	3·15	0·00	27 294
31 " ...	1·64	1·18	2·62	0·98	2·03	2·86	1·15	1·51	0·20	0·16	0·16	1·97	1·37	2·86	0·16	25 288
10 June ...	1·84	1·31	3·05	0·92	1·84	3·22	1·15	1·51	0·62	0·26	0·00	1·64	1·45	3·22	0·00	25 899
20 " ...	1·87	1·15	3·31	0·82	0·59	2·89	2·86	1·64	1·48	0·49	0·20	1·84	1·59	3·31	0·20	26 982
30 " ...	3·61	1·15	3·31	0·82	3·84	3·45	4·13	1·41	3·38	0·20	4·20	1·97	2·62	4·20	0·20	35 384
Half-yearly { Max.	9·09	8·56	9·19	8·24	10·37	10·99	7·64	9·45	6·89	7·71	9·19	9·29	8·80	10·99	6·89	99 494
Half-yearly { Min.	1·64	1·15	2·62	0·82	0·59	2·86	1·15	1·41	0·20	0·00	0·00	1·64	1·37	2·86	0·00	25 288

HEIGHTS OF WATER LEVEL OF THE NILE AT THE DELTA HEAD ABOVE LOW WATER IN FEET—*Continued.*

Date.	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	1861	Mean.	Maximum.	Minimum.	Corresponding Mean Discharges. cub. ft. p. s.
10 July ...	5·38	3·44	3·38	3·77	4·00	5·87	4·86	2·20	3·23	0·36	3·94	3·28	3·64	5·87	0·36	44 423
20 „ ...	6·14	6·40	5·25	5·51	5·78	8·34	7·75	4·51	3·45	1·71	5·38	4·20	5·37	8·34	1·71	61 240
31 „ ...	9·03	11·49	15·00	16·74	11·26	11·49	10·17	8·53	8·21	4·30	11·55	11·32	10·76	16·74	4·30	123 975
10 August...	15·86	17·88	15·69	19·75	16·74	15·20	16·97	13·69	10·67	17·07	17·17	17·23	16·16	19·75	10·67	200 063
20 „ ...	18·38	20·09	18·15	20·55	20·05	16·97	19·36	19·04	18·81	16·84	17·82	19·85	18·83	20·55	16·84	241 934
31 „ ...	19·36	20·35	18·48	20·90	20·22	18·25	20·35	19·39	19·36	17·66	19·04	20·18	19·46	20·90	17·66	252 193
10 Sept. ...	19·69	17·69	18·87	21·82	21·53	10·49	21·36	20·12	19·69	19·14	19·52	21·49	20·03	21·82	17·69	261 600
20 „ ...	20·12	18·37	19·55	23·60	21·99	15·36	21·79	19·76	19·03	19·14	19·69	22·42	20·07	23·60	15·36	262 262
30 „ ...	19·62	23·63	19·62	25·14	23·83	14·21	23·76	19·[illegible]4	18·18	18·71	20·09	25·43	20·94	25·43	14·21	276 850
10 October.	19·39	23·40	19·30	24·87	24·61	15·55	23·63	[illegible]	16·87	18·81	21·13	24·44	20·89	24·87	15·55	276 002
20 „ ...	18·38	21·89	18·61	23·50	23·98	17·75	22·45	17·27	17·24	18·51	23·86	22·80	20·52	23·98	17·24	269 776
31 „ ...	18·54	17·75	18·05	21·49	22·77	15·43	20·09	17·65	16·08	19·36	21·66	20·09	19·08	22·77	15·43	245 990
10 Nov. ...	15·92	15·36	15·10	19·17	18·51	14·77	16·90	14·60	15·17	19·04	17·88	17·52	16·66	19·17	14·60	207 703
20 „ ...	13·29	13·66	12·27	16·31	16·08	12·54	14·77	12·14	12·57	17·23	14·77	15·96	14·30	17·23	12·14	172 506
30 „ ...	11·81	12·44	11·13	14·31	14·44	10·86	13·36	11·16	11·16	14·44	13·06	14·37	12·71	14·44	10·86	150 049
10 Dec. ...	10·67	11·42	10·21	13·13	12·93	9·94	12·14	9·85	9·82	12·47	11·95	—	11·32	12·93	9·82	131 291
20 „ ...	9·85	10·24	12·73	12·18	12·14	9·06	11·06	8·99	8·89	10·99	11·16	—	10·66	12·73	8·89	122 683
31 „ ...	9·03	9·78	8·86	11·16	11·29	8·11	10·08	7·88	8·27	10·11	10·44	—	9·55	11·29	7·88	108 647
Half-yearly { Max.	20·12	23·63	19·62	25·14	24·61	19·49	23·76	20·12	19·69	19·36	23·86	25·43	20·94	25·43	19·36	276 850
Half-yearly { Min.	5·38	3·44	3·38	3·77	4·00	5·87	4·86	2·20	3·28	0·36	3·94	3·28	3·64	5·87	0·36	44 423

HEIGHTS OF HIGH WATER AT CAIRO ON THE RHODA GAUGE ABOVE ORDINARY LOW WATER.
According to ISMAIL SADIK PASHA.

Date.		Cubits and Digits.		Mètres.	Feet.	Estimation.
1848.	2 Oct.	24	6	7·70	25·27	Very high
1849.	7 Oct.	24	5	7·68	25·20	Very high
1850.	19 Sept.	21	20	6·46 ?	21·20	Moderate
1851.	3 Oct.	24	9	7·77	25·50	Very high
1852.	31 Aug.	21	8	6·35 ?	20·84	Moderate
1853.	1 Oct.	24	9	7·77	25·50	Very high
1854.	29 Sept.	23	23	7·55	24·78	Full
1855.	10 Sept.	20	18	6·20	20·35	Deficient
1856.	2 Oct.	24	8	7·75	25·43	Very high
1857.	13 Sept.	21	22	6·48	21·27	Moderate
1858.	6 Sept.	21	14	6·40 ?	21·00	Moderate
1859.	27 Oct.	21	7	6·32 ?	20·74	Deficient
1860.	17 Oct.	24	5	7·67	25·17	Full
186..	27 Sept.	24	16	7·92	25·99	Very high
1862.	22 Oct.	23	0	7·04 ?	23·10	Moderate
1863.	20 Sept.	25	1	8·11	26·62	Excessive
1864.	20 Sept.	19	21	5·95	19·53	Very deficient
1865.	18 Oct.	22	23	7·02	23·04	Moderate
1866.	27 Sept.	25	11	8·31	27·27	Excessive
1867.	11 Sept.	21	22	6·46 ?	21·20	Moderate
1868.	27 Aug.	19	13	5·87	19·26	Very deficient
1869.	11 Oct.	25	15	8·40	27·57	Excessive
1870.	14 Oct.	24	17	7·92	25·99	Excessive
1871.	27 Sept.	23	16	7·38	24·22	Full
1872.	20 Oct.	24	3	7·65	25·10	Full

NOTE.—There is evidently much error in the official reduction and in the original records—(*dressé par* M. Tissot).

CONDITION OF THE RIVER.

In Nubia, below Khartum, the course winds greatly, and is broken by rapids or cataracts in rocky soil or among hills, specially between Dongola and Wadi Halfa. The banks are generally sterile, and irrigation by inundation canals is excessively rare; although flood deposits, at a level higher than that of the flood itself in the adjoining river bed, indicate the possibility of effective irrigation from off-takes taken higher up stream. Navigation is difficult on account of the rapids; in 1857 two steamers arrived at Dongola after much effort. Malezieux proposed a navigable canal from Korosko to Abu

Hamid, supplied by water pumped from the Nile, but the expense would be enormous.

In Egypt, below Assuan and the first great cataract, the river is winding, and variable in depth, there are also shallows and local currents, rendering navigation difficult. Below Siyut the river is regular in course and in current; the result of the resistance of its clayey banks to the action of the river; and is freely navigable. At about 500 miles above Cairo the river enters a valley liable to submergence by flood to a mean width of about nine miles. Parts of it, however, are above flood level. The edges of the valley, bordered by deserts and hills on the Lybian and Arabian sides, are generally lower than the middle, where the river-bed runs in a self-raised embankment, due to successive deposits of silt.

Irrigation is facilitated by long dykes transverse the valley, and by inundation canals. The basin of Madinat el Fayum is also supplied during flood by the Bahri Yusuf, a watercourse partly canalised at one time, which receives Nile water near Siyut, and conducts it along the Lybian edge of the valley. The expenditure of water is on the whole very large. The depth of slime deposited by the water is estimated at 0·40 foot in 100 years, even in the river bed: its qualities are highly fertilising.

About half the extent of the valley in Upper and Middle Egypt consists of irrigated and cultivated land, amounting to nearly $1\frac{1}{2}$ million acres of cultivation dependent on the floods of the Nile. When these do not rise to 20 feet, or when they exceed 26 feet, the crops suffer seriously. Famine and desolation result, the people are then forced to borrow from Greek and Jewish usurers under crushing bargains, and are thus periodically driven to utter ruin.

There is not any existing canal for supplying irrigation water throughout the year. In 1875 two low-water canals were projected, with headworks at Keremat and Echment, east and west of the river; but these projects were not executed, as the scope of their irrigation was nearly limited to the Delta, and the works were costly.

In the Delta.—The bifurcation at the head of the Delta begins at 12 miles below Cairo; there are now only two main channels; the Bolbitine, discharging near Rashid, and the Phatnetic, discharging near Damiad. These were embanked, and a large number of inundation canals and channels constructed before

1840, under the rule of Mehemet Ali. The irrigated land in Lower Egypt, that is in the Deltaic lands which extend from Lake Menzalah to Lake Mariut, and close up to Cairo amounts to about 2 million of acres. One crop is grown with inundation water, and in many places a second and even a third by the aid of water raised with sakías and shadúfs from pits or wells, generally not exceeding 10 feet in depth.

In order to utilise the low water supply of the Nile in irrigating the Delta throughout the whole year, a dam was constructed at the Delta head. This highly ornamental project for raising the level of the water dates from 1846, and was nearly completed in 1850, under M. Moujel, Director of Works. It is one of the worst examples of hydraulic works. In fact, the French Barrage is a byword of reproach; it can hardly raise the water level to six feet, its self-acting sluices do not act, its base is exceedingly weak and bad and the whole structure is in a very dangerous state. A project was drawn up by English engineers in 1876–77 for constructing a dam adjoining it which should raise the water-level to a height of 15 feet, and thus effect the necessary irrigation; but this has not yet been commenced. The work of the Ponts et Chaussées being ineffective, the condition of the Delta as regards utilisation of the Nile remains little better than at the end of the rule of Mehemet Ali.

AVAILABLE SUPPLY OF THE NILE. (*According to* LINANT.)

Low Water Supply. — This varies very much from year to year, sometimes it is insignificant for a few days before the beginning of the floods.

Taking three cases observed (at the head of the Delta),

	Cubic feet per second.
In 1840, at highest part of low water supply	14 682
In 1834, the observations gave	61 645
In another year it was	23 882
These three give a mean low water discharge	33 403

Provided that one-fourth of this can be drawn off in perennial canals and utilised in irrigation of Lower Egypt, it amounts to 8 325 cubic feet per second.

Now the sufficient mean watering for the summer irrigation of crops in the Delta, including the small existing proportion of rice cultivation, is one cubic foot per second to 120 acres. If rice cultivation were adopted throughout, one cubic foot per second would water only 100 acres. Using the former figures —

	Acres.
The available supply is enough for	999 000
Whereas the actual summer irrigation in Lower Egypt is a cultivation of	950 000

The perennial canals do not, however, carry a sufficient supply from the Nile to water them properly by simple gravitation.

Flood Supply.—The available flood supply from the Nile is that inundating Upper and Middle Egypt, between Jabal Kilkilli and Cairo, and is equal to the difference between flood discharge at the former place and highest flood discharge at the latter. Setting aside two exceptional floods at Cairo of 343 987 and 334 093 cubic feet per second,

	Cubic feet per second.
Of the remainder the highest flood at Cairo is	288 418
And the highest flood at Jabal Kilkilli	447 325
Difference ...	158 907

Assuming that an effective good flood remains stationary for 20 days, (it varies from 15 to 20), and neglecting the balance during a few days of the earlier fall of flood ; also assuming that the cultivable land above Cairo is 1 920 000 acres, of which 1 500 000 acres are below flood level, the results are thus in total quantities—

	Cubic feet.
20 days' supply at 158 907 cubic feet per second	274 591 296 000
Loss by evaporation	749 296 000
Utilised on 1 500 000 acres	273 842 000 000

Which is equal to a supply in cubic ft. per second of 158 565 c.f.p.s.

This represents the ordinary flood cultivation carried on for ages, and experience has shown that it is sufficient for good

crops. Taking out the rates per acre and per cubic foot per second of supply from the above they are—

Total supply for each acre	182 561 cubic ft.
Total depth of irrigation over the whole ...	4·19 feet.
Current supply to each acre continuously during 20 days	0·1057 c.f.p.s.
Acreage irrigated by 1 cubic foot per second continuously during 20 days	9·46 acres.

ALTITUDES ABOVE MEAN SEA LEVEL OF PLACES IN NUBIA.

Collected by M. TISSOT.

Distances by river from Khartum, in miles.		Altitudes in feet.
0	Khartum; at confluence of the Blue Nile	1240·53
114	Shendy. Highwater Level in 1866	1192·07
	" Low water " 1867	1164·27
199	Confluence of the Atbara	1166·36
218	Berber	1147·99
381	El Kab	964·53
403	Umderas	935·82
453	Gerindid	773·30
664	Hannak; at cataract	687·12
712	Kaibar "	674·09
820	Dalah	626·17
906	Wadi Halfa	420·07
1155	Philœ (7 miles from Assuan)	331·16

ALTITUDES ABOVE MEAN SEA LEVEL OF PLACES IN EGYPT.

Collected by M. TISSOT.

Distances by river, from Assuan in miles.		Altitudes in feet.
0	Assuan (levels unconnected with Siyut series).	—
330	Siyut, ordinary low water of 1872 at off-take of Ibrahimiah	147·40
379	Dairut, Plinth of Sluice-bridge of the Ibrahimiah Canal	125·04
415	Miniah, at Quay Shekh Fuli	132·61
	" Plinth of Sluice-bridge of the Ibrahimiah ...	116·01
	" High water Level of 1870	131·73
	" Ordinary low water of 1871	107·28
491	Fashan, ordinary low water of 1871	82·87
511	Benisuef, ordinary low water of 1871	75·06
583	Cairo, top of parapet at gauge, I. of Rhoda	67·92
	" Level of great Mastaba to the west	44·40

ALTITUDES ABOVE MEAN SEA LEVEL OF PLACES IN EGYPT—*Continued.*

Distances by river in miles.		Altitudes in feet.
583	Cairo, Level of Mastaba of the Pharaohs to the east	35·62
	„ Zero on the Gauge of cubits	28·27
	„ Theoretic ordinary low water of the Rhoda gauge	39·71
	„ High water of 1869	67·31
	„ Quay of the Waterworks Co., Old Cairo ...	67·39
	„ Zero of the gauge at that Quay	31·05
	„ Theoretic ordinary low water on this gauge ...	39·26
	„ High water level of 1872	64·36
	„ Kasr el Nil Bridge, pavement of footway ...	77·78
	„ Theoretic ordinary low water at this bridge ...	39·05
	„ High water level of 1872	64·16
599	Delta head, Moujel's Dam, zero of gauge	35·03
	„ Lowest water observed in 1859...	34·46
	„ Highest „ „ 1869...	61·76
632	Benah (Damiad branch) high water level of 1863 ...	47·29
	„ Ordinary low water	22·84
674	Kafr Zayat (Rashid branch), high water level of 1869...	33·02
	„ Mean low water	4·33
	„ Zero of the gauge at the bridge	2·49
708	Atfah (Rashid branch) at off-take of the Mahmudiah Canal, high water level of 1869	14·60
	„ High water level in the canal	8·04
	„ Ordinary water level in the canal	4·92
756	Alexandria, high water level in the Mahmudiah Canal at the outlet	7·29
	„ Ordinary water level in the canal ...	4·17
	„ Highest sea level known, 9 Feb., 1860 ...	2·36
	„ Lowest sea level known, 10 March, 1860, below mean sea level, or negative ...	—1·58

ALTITUDES ABOVE LOW WATER OF THE MEDITERRANEAN OF VARIOUS PLACES IN EGYPT. *According to* LINANT.

	Altitudes in feet.
Low water in the Mediterranean	0·00
High water „	1·25
Low water in the Red Sea at Suez	2·43
High water „	7·94
Land at Shaluf; low water of Isthmus basin	11·29
„ lowest water	6·10
Serapeum, near the Monument	16·07
„ hillock of Monument	42·65

ALTITUDES ABOVE LOW WATER OF THE MEDITERRANEAN OF VARIOUS PLACES OF EGYPT. *According to* LINANT.—*Continued.*

	Altitudes in feet.
Ruined Canal at the fork towards Shek Ennedak towards S.W.	9·84
" towards S.E. near the fork	12·20
Lake Timsah, mean	9·84 to 16·40
Gisr, on land bank highest point	52·49
Marshes of Fardanah	2·95
Mean level of Wadi lands from Saba Biars to Abassah	21·65
Abu Balah, neighbourhood	11·94 to 14·76
Wadi, Old Pilgrim's Lake near Gawarni dyke	9·84
Zagazig, off-take of Wadi Canal in Baha Moez, low water	159·76
" " " " high water *	330·06
Off-take of the Khalig of Cairo, low water	46·13
" " high water	71·17

DISTANCES IN NUBIA AND THE SOUDAN ON TELEGRAPH LINES.

According to COLONEL STEWART, 1883.

	Miles.
Khartum to Shindi	90
Shindi to Berber	95
Berber to Dahaid	120
Dahaid to Debbah	95
Debbah to Dongola	100
Dongola to Halfa	225
	725
Berber to Goz Rejeb... ...	180
Goz Rejeb to Kassala ...	70
Kassala to Fillik	40
Fillik to Suakin	230
	520
Kassala to Relloh	52
Relloh to Amadeb	44
Amadeb to Koren	74
Koren to Massuah	110
	280

	Miles
Khartum to Messelemia ...	80
Messelemia to Senar	75
Senar to Fazogla	180
	335
Khartum to Abu Gurad ...	—
Abu Gurad to Korti	135
Korti to Bara	10
Korti to Obeid	25
Obeid to Foggia...	175
Khartum to Abuttaraz ...	85
Abuttaraz to Gedarif... ...	120
Gedarif to Kassala	132
	337
Gedarif to Gallabat	130
Gedarif to Ghizah	—
Messelemia to Kana	—

* Probably this is an error; but the reduction is right.

CANALS.—EXTENT AND NUMBER OF CANALS IN

Mudiriah.	Navigable Canals.		
	Number.	Miles.	Acres.
In Upper Egypt. 1. Esnah	2	48	723
2. Keneh	8	79	735
3. Girgah	40	302	3 960
4. Assiut	7	116	2 679
Middle Egypt. 1. Benimazar and Miniah ...	2	151	3 233
2. Benisuef	5	96	1 339
3. Fayum	1	14	315
Total	61*	826*	12 985*
Lower Egypt. 1. Gizah	0	0	0
E. 2. Galliubiah	7	71	1 136
3. Sharkiah	18	389	8 737
4. Dakkaliah	2	85	1 272
C. 5. Menufiah	17	223	3 815
6. Garbiah	8	239	5 604
W. 7. Behera	2	184	1 620
Total	52	1 091	22 184
Total for all Egypt ...	113	1 917	35 169

* NOTE.—These three totals are incorrect. The official returns for 1873 contain much discrepancy,

… CANALS IN …GYPT IN 1873, ACCORDING TO OFFICIAL RETURNS.

	Unnavigable Canals.			Canals of all sorts begun between 1863 and 1872.	Number of Hydraulic Appliances.			
Acres.	…umber.	Miles.	Acres.	Number.	Sakiahs.	Shadufs.	Tabuts.	Steam Pumps
723	9	31	93	...	1 910	5 808	...	...
735	14	132	859	...	1 353	7 473	...	...
3 960	19	52	156	...	383	32 929	...	...
2 679	63	154	1 143	...	704	14 633	...	...
								...
3 233	71	200	615	...	23	715	...	...
1 339	52	119	477	...	107	715	...	...
315	111	1 078	1 323	...	448	413	...	...
12 985*	339	.1 766	4 666	0	4 928	62 686	...	...
0	9	198	1 769	0	...	...	...	...
1 136	27	223	964	9	3 072	912	...	...
8 737	…81	1 135	4 716	17	4 675	5 245	346	33
1 272	28	361	4 644	9	8 000	445	4 400	100
3 815	24	209	695	21	4 127	503	693	64
5 604	75	702	6 252	40	4 891	615	195	196
1 620	73	1 989	34 203	16	391	102	1 292	83
22 184	…17	4 817	53 243	112	25 156	7 822	6 926	476
35 169	…56	6 583	57 909	112	30 084	70 508		

…uch discrepancy, …erhaps intentional misstatement. The statistics were afterwards suppressed or recalled.

LOW-WATER DISCHARGES OF PERENNIAL CANALS (SEFI), corresponding to a river discharge of 33 403 cubic feet per second at the head of the Delta, according to Linant.

Region.	Canal.	Cubic feet per second.	Clearance annually in millions of cubic feet.
Upper Egypt:	The Ibrahimiah	—	—
Provinces East of the Damiad branch:	The Ismailiah	—	—
1. Gizah	The Sherkawah ...	202·75	9
	The Bessussiah ...	105·95	3½
	The Wadi Tumilat	—	—
	Bahr Moez ...	0	0
2. Galliubiah. 3. Sharkiah. 4. Dakkaliah.	Metyabecha ...	80·67	5¼
	Donded	44·19	5¼
	Bukiah	44·19	5¼
	Mansuriah ...	127·14	10
	Sherkawah (branch)	54·77	7
	Nahran ...	—	—
		659·66	45¼
Deltaic Provinces:	Manufiah ...	—	—
5. Manufiah. 6. Garbiah.	Sersawah ...	70·31	4¼
	Baguriah ...	211·90	4
	Bahr Shibin ...	706·34	247
	Ataf ...	70·63	—
	Messid el Khradar.	82·43	13
	Bekerem ...	61·22	4½
	Sahel ...	—	—
		1202·83	272¾
Provinces West of the Rashid Branch	The Bekera ...	—	—
7. Behera.	The Khatatbah ...	198·05	64
	The Mahmudiah...	183·94	88
		381·99	152
	Incomplete Total	2244·48	470

The Drainage Channels of Egypt,

according to Linant's "Memoire sur les Principaux Travaux exécutés en Egypte." Paris 1872-73 (*Bertrand*).

Region.	Drainage Channel.	Discharging into
Upper Egypt ...	The Sohagiah ...	The Bahr Yusuf.
	The Bahr Yusuf ...	The Fayum; also on west of the Rashid branch.
The Fayum ...	The Bahr Bela Ma ...	Lake el Korn.
	The Bahr Neslat ...	Lost towards the S.
Provinces east of the Damiad branch ...	Wadi Tumilat (Bulbeis) ...	Lake Timsah
	Abu el Ardar (Pelusiac) ..	Lake Menzaleh.
	Salahieh Canal ...	——
	Bahr Moez (Tanitic) ...	Lake Menzaleh.
	Bahr Serayer ...	
	Bahr es Sagir (Mendesian)	
Deltaic Provinces ...	The Baguriah ...	Lake Burlos and the Sea.
	The Bahr Shibin ...	
	The Bahr Kalin ...	
	The Bahr Saidi ...	
Provinces west of the Rashid branch ...	The Terriah and others ...	Lake Mariut. Lake Etko.

Works under Mehemet Ali.

Most of the modern irrigation works of Egypt have been made during or since the time of Mehemet Ali. Every year the greater part of the population—nearly all—were at work on them. Annually 400 000 men, or 800 000 workpersons including women and children, worked in the levy; while others constructed the small channels and dykes near their own villages. The contingents of labourers under village sheikhs made their separate pieces of canals which were afterwards joined, sometimes curiously. The engineering was haphazard, the direction was ill-managed, and probably entirely unpaid.

In 1830, a Direction of Works was constituted; in 1835, a Minister of Public Works was appointed, and a body of engineers formed by Linant under a bureaucratic system.

The contingents of labourers were doubtless often supplied

from villages that did not participate in the advantages of the canal or work on which they were employed. Even in annual clearances this happened continually, as, for example, in the Khatalbah Canal, for which 30 000 men are required for forty days; the province of Behera, benefited by it, could only supply 15 000 men. In most cases the forced levies benefited themselves by their own labour, but certainly not in all. The earthwork done in one year, 1846, amounted to 1 800 million cubic feet. The period of Mehemet Ali was from 1816 to 1850. The larger perennial canals began about 1836.

The works of his time were :—

1. The construction of the interior new Abukir Dyke.

2. The construction of the Pharoniah Dyke for closing the Pharoniah Canal, which drained the Damiad branch to the benefit of Rashid.

3. The construction of the Bibah Dyke, protecting Lake Menzaleh and the land on its banks from flooding from the sea, during the low-water state of the Nile.

4. Reconstruction and revetment of the Koshekah Dyke.

5. The construction of the Bahr Bela Ma Dyke, and rebuilding of the Tamiah Dyke.

6. The new Illáun Dam, at the entrance of the Bahr Yúsuf into the Fayúm; the old one was made in the time of Yúsuf Salahuddin.

7. The Canal Mahmudiah.

8. The Dock and Basins of Alexandria.

9. The Bahr Shibiń regulating Dam.

10. The Survey of the irrigated lands and canals of Lower Egypt.

Projects of the time of Mehemet Ali.

1. Navigable passage of the Cataracts of Wadi Halfa and Assuan.

2. The Jabal Kilkilli Canal.

3. The Reclamation of Lake Mariut.

4. A navigable Canal from Damiat to Rashid.

5. The conversion of the Khalig Cairo Canal into a perennial canal.

6. Khalig Zaffránah Canal.

7. The Dam at the Delta head, begun in 1847.

8. Some deep borings for water supply.

Later works in Egypt.—In 1857, under Said Pasha, the waterworks of Alexandria, and the waterworks of Cairo.

1859–69.—The Ship Canal from Port Said to Suez.

After 1863.—The Ibrahimiah Canal, navigable. The Ismailiah Canal, navigable.

In 1865.—Moujel's Dam at the Delta head.

In 1867.—Port Ibrahim at Suez, under Ismail Pasha.

In 1870.—The enlargement of the Port and Harbour of Alexandria.

In 1872.—The Behera Canal, navigable.

The Manufiah Canal and the Sherkiah Canal, commenced about 1847. Probably these were abandoned, and recommenced in modern times.

Ship Canals.

The canal from Port Said to Suez was begun on 22nd April, 1859, and executed by forced labour until 1864, when steam dredgers were employed in greater number; it was inaugurated as open on 17th November, 1869.

The surveys, the project and general design were those of Linant Bey, a Frenchman in the Egyptian service; the financial management and speculative establishment of this great undertaking was chiefly that of Ferdinand de Lesseps. The expense of construction and establishment until the end of 1870 amounted to £17 681 836: this was provided by a share capital of £8 000 000; by £4 000 000 raised on bonds; £4 560 000 contributed by the Egyptian Government, apart from shares held by them.

The Government also incurred the cost of £400 000 for the Wadi domains, £860 000 for the fresh-water canal, and for other accessory works at harbours, lighthouses, &c., incurred an expense of £8 293 080.

The total amount of excavation was 265 million cubic feet; excavation for maintenance was afterwards continued at the annual rate of 17 600 000 cubic feet. The minimum depth of water is 26½ feet; the mean depth 28 feet, the bed width 72 feet; the width at water level varies from 190 to 328 feet.

It will be needless here to enter into the details of the course, and of the works and excavation; the former is familiar to

all who have frequently passed through the canal, and the works afforded little novelty or engineering interest, as far as execution was concerned, beyond the employment of steam dredgers and shoots on a large scale. The canal would probably never have been attempted by free labour in the first instance, and would never have been completed by steam power, had it not been supported so strongly by the Viceroy throughout.

The initiation of the undertaking and the causes leading to its execution are of interest, as they indicate an amount of intrigue, conflicting with the rights of the projector, that amounted to nearly perfect robbery. This was supported by some thousands of shareholders of the same nationality for their own advantage with utter shamelessness.

Ancient ship canals from the Pelusiac Gulf to the Erythrean Sea certainly existed. One made under Nekhos and Darius; that was never perfectly complete, though it was certainly used during the Ptolemaic period after further improvement, about 284 B.C. Under Hadrian, A.D. 117, a canal existed, probably a modification of the former, perhaps a mere restoration.

In the time of the Khalif Omar (A.D. 663) a canal was made by Amru to Kolzum (Suez?), which was used by ships for a comparatively short time. All of these canals followed the natural course of such works when left to take care of themselves: they silted up. The ruins, traces, hillocks, &c., were found by Linant in his researches and during his levelling operations.

The more modern projects that arose from time to time show that the matter had not been entirely forgotten. In 1519, Sultan Selim, after his conquest of Egypt, had some intention of re-opening the communication. In 1621, Sultan Mustafa, son of Muhamat III., Sultan at Stambul, sent Baron de Tott to investigate the matter. In 1766, fresh emissaries were sent from Stambul to Egypt to make inquiries and studies.

The first purely Egyptian initiative was that of Ali Bey, in 1788 (who had ruled for nearly 28 years?); he built ships on the Red Sea, and certainly had the intention of proceeding further.

In 1799, during the French occupation of Egypt, Monsieur Lepère, official chief engineer, drew up a project, which was good and careful in design, but also slightly erroneous on account of errors in the survey and levels. The records of his operations and designs appear to have been utilised afterwards; though

the expulsion of the French from the country rendered them useless at that time.

Under the belief that the difference of level between the Red Sea and the Mediterranean amounted to nearly 33 feet, the project of Lepère was not that of a direct canal from sea to sea. Seeing also the difficulties and large expense involved in establishing a good port or roadstead in the Mediterranean, his project was for a canal, or series of reaches, suited to vessels drawing 13 to 16 feet of water, communicating with the Bahr Moez and the Pelusiac branch of the Nile, but supplied in part of the course by fresh water from the old canal of Trajan leading from Cairo. Probably he intended also to deepen the Pelusiac branch, which at low water was in some places only 5 feet deep; or he may have intended to form a communication navigable at high water. Even at its best, this was certainly a very defective project at a time when steam-dredging and steamships were unknown. Had it ever been executed, it would probably have resulted in something parallel to Moujel's Dam, as regards effect and reputation. But there is little doubt that Lepère contemplated more direct communication with the Mediterranean by an additional reach of canal; though this did not form part of his project as drawn up.

The present project, that of Linant de Bellefonds, a French engineer in the Egyptian service from 1825, was mentioned by him in 1830 and 1833, to Messrs. Mimant and De Lesseps, then French Consuls in Egypt; this project was entirely ready in 1840, and was then communicated to various European Ministries. In 1841 some arrangement was effected with Mr. Davidson, Director of the Peninsular and Oriental Company; in 1842 the Indian Government welcomed the proposal. In 1845 the Duc de Montpensier took Linant's plans and reports to France, and supported the proposal; eventually, in 1847, a French company (or syndicate) was formed to consider the subject. This resulted in the despatch of three sets of engineers from France, Austria and England, to examine the levels and soundings. At that time the Viceroy, Mehemet Ali, disbelieved in the eventual success of the project, but appointed Linant to aid the expedition in every possible way. The levels resulted in showing a difference of level of 8·56 feet between the quay surface at Suez, and low water in the Mediterranean; and the

greatest fall at high water between the two seas at 7·5 feet. Yet, in spite of these results, nothing was done to further the project until July, 1853, when M. Favier, a French official engineer, published a letter, casting doubts on the levels of 1847, and supporting the levels of 1799, in which he had taken part. Opinion hence remained divided. On February 3, 1853, Linant received orders from the Viceroy Abbas Pasha, to verify the levels. These operations showed a difference of level of 7·94 feet between low water in the Mediterranean and extreme high water at Suez. Allowing for some differences in datum employed in the series of 1847 and 1853, the difference in actual result amounted to 0·6 foot. The probable cause of error in the levels of 1799 was traced to the bed level of an old canal, filled up with sand brought by wind. This formation was probably treated as simple bed level, and thus accounts to some extent for the error of 25·65 feet.

These verifications appear to have decided the matter, for in November, 1854, the speculator, De Lesseps, announced to Linant that the project was decided on, and that Linant was to be the engineer in charge of the works indicated in his own project. Shortly afterwards, Moujel was associated with Linant as colleague, with the view of superseding him, after utilising all his information and experience. A fresh set of small plans was furnished by Linant, for use in France, to draw public attention to the scheme, and about this time the Emperor Napoleon III. expressed his extreme pleasure to De Lesseps.

Whether at this early period this speculator had represented himself as the proposer and designer, or had merely allowed it to be believed, is a matter unknown generally; but it seems clear that he obtained firmans of concession in his own name. Preliminary works in picketing the course of the canal, staking sections, &c., were then undertaken by Linant. In September 1855, Linant joined De Lesseps in France to aid in the formation of the Suez Canal Company. A commission of engineers and others, formed under the auspices of De Lesseps, arrived at Suez on 15th December, 1855, and left on 31st December. A second firman was obtained by De Lesseps from the Viceroy, which ousted Linant from the general engineering management, and reduced him to the post of Resident Engineer on the works. Conrad, a

Hollander, was appointed engineer in charge of the whole. Linant, not wishing to embroil the scheme, consented to this arrangement after it was effected; and delivered his series of plans.

The levels were again verified in 1855 and 1856, with results varying to about 1·6 feet from those of 1853.

The engineers appointed by the Suez Canal Company departed very little from the designs of Linant, and merely superintended the work of the contractors, which was in accordance with his plans. Later there was some pretence about setting aside these plans, ignoring them, and about having acted on others; as money had been voted for the purpose in July, 1857. The acknowledgment of Linant's plans was made in the *procès-verbal*, dated 6th June, 1858, by De Lesseps and Ruyssenears. This *procès-verbal* was annulled on 16th January, 1859, at the desire of Said Pasha, who at last understood the treachery of De Lesseps towards Linant, and saw that he himself was being manipulated also.

After 1859, Linant retained his position as Director of Egyptian Public Works, and superintended the construction of the Ismailiah, or fresh-water canal.

The works commenced actually in April, 1859; but in 1863, after the death of Said Pasha, when forced labour was abolished by his successor, difficulties arose with the company about the concession. At that time the excavation had been 154 million cubic feet, effected by 18 000 labourers at a cost of £110 000, of which about a half had been paid to them for work. There remained 837 million cubic feet of dry excavation to be yet done. The Egyptian Government was compelled under arbitration to pay heavily for withdrawing the privilege of employing forced labour.

These details, showing the amount of intrigue carried on in matters of concession and of public works, are the more needful, as even in 1884, some English newspaper editors remain who write of De Lesseps as engineer of the Suez Canal; whereas the whole credit of the affair, apart from market-rigging, justly is due to the hydraulician and real engineer, Linant de Bellefonds. Even in France, where they should have been better informed, it was necessary that the journal *L'Epargne* should expose the deception in an article of 31st March, 1872.

The stupid opposition to the Canal scheme by Stephenson and other English engineers (so termed) is accounted for by the fact that they were almost all merely rich speculative engineers, destitute of engineering ability, and of experience in hydraulic matters. While this opposition remained at full height, the compiler of this book declared the advisability of the execution of the Suez Canal, pointing out also that the expenses of efficient maintenance would necessarily be high. These views were also stated in his "Hydraulic Manual," first edition; written several years before its publication.

The project of doubling the Suez Canal to accommodate the increase of traffic is now receiving public attention; the difficulties lie in matters of cession of power and of admitting the principle of the claim to double vested rights that are already too large. The utilisers of the canals are trying to reduce the powers of the proprietors before further shackling themselves. Mutual concession must evidently precede the execution of any such project.

Canals in Upper and Middle Egypt.

1. *The Ibrahimiah Canal.*—This large canal has its headworks at Siyút, it flows by the side of the river to Mankabat, and continues to Manfalút, crossing the Bahr Yúsuf, and supplying it with water for the irrigation of the Fayúm; it afterwards ends by joining the old canal Fechn.

The canal Fechn has its off-take opposite Madinat-el-Jahel and delivers into the canal of Benisuef, which has its off-take near Balanka and Mataya.

The dimensions of the Ibrahimiah channel at its off-take are, in bed width 115 feet, and at ground level about double that. Its summer depth of water is nominally 4·8 feet, but, owing to imperfect clearance, is actually at low water only 3 feet; the fall of the bed is 6·5 per 1 000. The section diminishes at Mellawah, and is more reduced further on; the fall also is not uniform. With an assumed velocity of 0·564 foot per second, the discharge would be 344 cubic feet per second (such are correctly reduced values); with an evaporation from a surface of canal 1 940 000 square feet, amounting to 71 cubic feet per second; the net discharge utilisable is 273 cubic feet per second, or sufficient for irrigating 22 228 acres, at the rate of 1 cubic feet per second to

81·4 acres of sugar-cane crop. Another calculation, on the assumption of clearance to a greater depth, involves a reduced section with the same velocity; the discharge is hence reduced, and then only 12 320 acres are irrigated. The mean supply utilisable is hence given at 212 cubic feet per second, which will irrigate 17 270 acres of sugar crop.

These results are low, allowing for irregularities and exceptional circumstances, including those of unusually low water. In flood the flow is more irregular than at low water, and the velocity in the Nile can never be predetermined for any water level.

For the flood season lasting 100 days in the Seifi canals below low water, the section of the Ibrahimiah may be taken at 493 748 square feet, and the velocity 4·32 feet per second, this gives a discharge of 2 161 cubic feet per second; adopting a mean between high flood discharge, the calculation can be based on 1 169 cubic feet per second throughout the 100 days, and allowing a depth irrigated of 10 feet of water over the land, the acreage irrigable by its flood is 213 206 acres of low land, mostly in the Fayûm.

The advantage of summer irrigation by a Seifi canal is doubtless very great, but the inconveniences resulting from large quantities of silt, and from high velocities during flood, are very serious.

The length of the Ibrahimiah canal is given as 93 miles, and the amount of earthwork executed in it as 1 342 million cubic feet. Its breadth is 230 feet throughout the first 38 miles, and 161 feet for the rest of its course.

2. *The Sohagiah* is a natural overflow channel or drainage channel, taking its supply from the Nile during flood, between Siyût and Manfalût; its course is then N.W. for some distance until arriving at the watercourse level, skirting the Lybian desert and running in the depression between it and the elevated Nile valley. Continuing in this natural depression it eventually arrives at Geldah, west of Mellawah, where it tails into the Bahr Yusuf or Yusufi, which is a continuation of the same depression. Such has been its course certainly since 1832, and perhaps for ages; as it is not known when the Nile first overflowed its banks at the head of the Sohagiah. The Sohagiah serves as an inundation canal along its course through the districts of Sohag and

Tahta ; its length being in all 41 miles ; and its surface 2 434 acres. Its head was probably regulated for some time by temporary headworks or off-takes of brushwood and mud ; it now has permanent headworks, one or two stopdams at intervals for controlling its supply, and, however irregular its course or its section, it is now a permanent inundation canal. Its breadth is given in the returns as about 475 feet ; perhaps erroneously.

3. *The Yusufi*, or *Bahr Yúsuf* is a watercourse or overflow channel of the same sort as the Sohagiah, but of greater length, and more utility. It breaks out of the Nile about 18 miles above Rhoda, takes a N.W. course for about 15 miles, and then, uniting with the tail of the Sohagiah, follows the depression between the elevated Nile valley and the skirt of the Libyan desert, until arriving near Illaún, the gorge of entry into the Fayúm basin of depression. Its course as far as that point is about 150 miles, during the whole of which it serves both as a drainage channel for lateral overflows of water from the artificial basins of the Nile valley, and as an inundation canal for the land near its own banks. As it is fed by springs in its bed, resulting from infiltration from the Nile above it, it is also a dry season or perennial canal to some extent. It has now permanent headworks at its off-take, and a few stopdams in its course. At one time, perhaps in the time of Saltań of Yúsuf-ud-diń, it had none, or only temporary headworks, and was in an entirely unregulated, uncanalised state. At present it serves important objects both as a flood canal and as a perennial canal, although its condition throughout most of its course is rough, untrimmed, and varying little from its original natural state.

From the fork at the Illaún gorge, one branch of the Yusufi enters the Fayúm through a regulating dam, and continues to a storage basin, near the town of Madinet ; on this the whole of the province is dependent for irrigation water, both in flood and in dry weather. In the Fayúm therefore the Yusufi assumes the conditions of a river.

From the fork at Illaún, the other or direct branch of the Yusufi proceeds northward, skirting the Libyan desert, and continues as far north as the head of the Delta. Beyond that even there is some depression of the ground continuing as far as Lake Mariut, and this might also be termed a continuation of the Yusufi, as it probably was so at some remote period. But

that must have been before the floods of the Yusufi had forced an entrance into the Fayúm, and enabled it to spend so large a portion of its water in that province. The silting up of the northern branch of the Yusufi, or its drying up, must necessarily have followed that event.

The following are the lengths of the Yusufi in the various provinces, according to returns :—In Siyut 33 miles, in Miniah 81 miles, in Benisuef 38 miles, and in Fayúm 14 miles; altogether 166 miles. But the continuation of the Yusufi in the Fayúm takes some local name.

4. *The Bahr Bela Ma.*—This is one the natural drainage channels of the Fayúm, formed by an overflow from the Yusufi, near Awarat el Makta. It takes a northerly course, and acts as an inundation canal, continuing to Tamiah, where is a regulating dam for storing and drawing off water. The course of this ravine continues nearly northward to Lake El Korn, or Kerun.

5. *The Bahr Neslat* is a large ravine, formed by an overflow of a large basin supplied by the Yusufi; its outfall is partly regulated by a dam in a large dyke, built for this purpose. It acts to some extent as an inundation canal to lands below. Its course is southwards, and it appears to lose itself in that direction, probably supplying some natural depression with the remnant of its flood waters, which speedily evaporates.

Canals in Provinces east of the Damiad branch of the Nile, in Galliubiah, Sharkiah, and Dakkaliah.

1. *The Ismailiah Canal.*—This canal was originally intended to follow the course of the ancient canal of Trajan, from the Nile near Cairo to the Red Sea. It was provided in the firman of 30th November, 1854, that it might be constructed as an adjunct to the ship canal. The intentions were to form two branches from it at Lake Timsah, one going to Pelusium, the other to supply drinking water to Suez, and to irrigate 100 000 acres during flood; while the main channel was to be navigable for barques and small steamboats from the Nile to the ship canal. The amount of supply appeared afterwards sufficient to enable dry-weather irrigation of 60 000 acres to be effected.

The design was drawn up by Linant, in December, 1856. The French company proposed several important modifications;

but eventually a commission approved of the following design, which was partly executed.

The project consisted in taking water from the Nile at Kasr-el-Nil, through a dam provided with sluices and a lock for navigation, into a canal following the course of the ancient Khalig Zaffranah as far as Kafr Hamza, thence to Menayer, onwards skirting the desert to Gawarnah, where, crossing the Wadi Timulat, it afterwards follows the northern part of that Wadi as far as Nafishah, near Abu Balah.

The bed level was nowhere to be below ordinary low water of the Nile. During the low-water season the supply was to be effected by hydraulic machines raising water into it to a height of 6·56 feet. The canal to be divided into several reaches by regulators, to economise water and reduce the fall. During flood, from July to February, each reach to be filled to the level of the land to be irrigated. The four regulating dams with sluices and locks to be placed at Kasr-el-Nil, Kafr Hamza, Bulbeis, Gawarnah; at the last reach, and in each of the two branches going to Suez and to Lake Timsah, three locks besides. This canal was capable of irrigating 31 000 acres of additional or unirrigated land on both banks during flood.

The company engineers afterwards altered this canal by abolishing the reaches, and adopting free-flow; and by making it partly a Seifi or dry season canal, increasing its depth to 6·56 feet below low water of the Nile. They then reverted partly to original project.

Eventually the canal was abandoned to the Egyptian Government. A mixed project, consisting of several reaches of canal having different depths, and stop-dams acting to different levels was the result. A temporary supply of water through the Shubra Canal was employed, and the works left in an incomplete condition, without any headworks at Kasr-el-Nil.

The length of the Ismailiah Canal is given as 61 miles, and the amount of earthwork in it as 388 million cubic feet.

2. *The Sherkawah Canal*, made in 1840 under Muhammad Ali, has its off-take near Cairo, above Shubra, near the village of Mansurah. It is to the south of the remaining canals, and has a far larger discharge, owing to its greater fall and direct course. Its off-take is free from silt. It supplies water to the whole province of Galliubiah, and divides into two branches, the

Shibin and the Kanater, which fall into the canal going from Zagazig to the Wadi Tumilat Canal; it supplies the Ismailiah Canal, and continues beyond the Wadi Canal to Horbait, Salhiah, and the marshes near Lake Menzaleh. It also irrigates rice-fields from Mansúrah (town) to Damiat. Its length is 18 miles.

3. *The Wadi Tumilat Canal.*—This is not supplied direct from its off-take in the Bahr Moez at Zagazig, but depends on the Sherkawah and the Bessussiah Canals for supply; also on a provisional off-take from the new canal from Shubra to Nemriah, or intended freshwater canal for the supply of Suez.

The Wadi Canal was made in 1828 expressly to supply a part of the Sherkiah province, lower than the rest, called Wadi Tumilat. This Wadi was formerly supplied in excess during floods from the neighbouring higher lands. A drainage channel was first made to Abu Balah and Lake Timsah, but it was not deep enough to carry off the collected waters. Besides this disadvantage, the Wadi Tumilat did not receive any water in the dry season; hence no crops could be grown at any time in the year.

Muhammad Ali then caused dykes and channels to be made to stop the flooding and to drain the land into lake Menzaleh. He also made the Wadi Tumilat Canal for summer supply; but originally it drew its water from the Bahr Moez, in which there was plenty available. Afterwards, when the supply in the Bahr Moez dwindled to little or nothing, the Wadi Tumilat Canal drew on the other canals before-mentioned.

4. *The Bahr Moez.*—This was the Tanitic branch of the Nile; in 1837 it was navigable all the year round, but latterly silted up.

It had headworks at Mit Radi, near Benha, on the Damiad branch of the Nile, and after a course of 92 miles entered Lake Menzaleh near the ruins of San, an ancient town. It was named after Moezuddin Sultan, about 970 A.D.

5. *The Nahran Canal*, watering the district of Azizi, in the province of Sharkiah, is 167 miles long, and has a water surface of 685 acres.

6. *The remaining four* perennial canals of these provinces, mentioned in the list, carry their waters northward. The Mityahecha irrigates land between Semballawenah, and the

Bahr Moez. The Donded and Bukiah supply lands of Sembal-lawenah, Telbani, Shubra, Kor, and between Sunah and the Bahr Serayer. The Mansuriah waters land as far as Mansurah, and supplies the Bahr Serayer for cultivation as far as Menzaleh. The discharges of these four canals are given in the list; but no details of the works are forthcoming, beyond the fact that they all have regulating dams at their off-takes.

Canals of the Middle Delta in Manuffiah and Garbiah.

1. *Bahr Shibiñ Canal.*—The Bahr Shibiñ is an old watercourse or natural drainage channel; in time of flood it also served as an inundation canal; and from the large amount of water it then delivered was productive of much damage. It hence required regulating as a flood channel, and was at the same time partly formed into a perennial canal, by making a regulating dam on it, forming a new or altered course, and supplying it above the dam through a new channel of supply. Thus the old watercourse was transformed into a canal. In 1839 and 1840, the Karinein regulating dam was constructed under Linant, not merely for the amelioration of the Bahr Shibiñ, but rather to serve as a preliminary to the construction of the larger dam at the head of the Delta, the designs for which had already been made under the joint labours of Linant and Moujel.

The Karinein dam was built to one side of the old Bahr Shibiñ channel, in a depression that afterwards became the new water channel.

The dam with its wings was 328 feet long, and 121 feet wide over all, with a footing 33 feet wide above the dam itself, in stone-boulder work. The foundation walls were in rubble, 4·2 feet thick, with a course of brickwork 1·64 feet high, bonded with a facing of ashlar throughout the length, and piers of ashlar. It had ten arched passages, 16·4 feet wide, the intermediate piers being 9·8 feet wide and 29·5 feet high to the level of the crown of the arches; the whole being in ashlar. The foundation surface was 6·56 feet below ordinary low-water level. On the right bank was a lock for navigable passage, 23 feet wide and 23 feet long, having a movable sliding wooden bridge over it. The foundations were set dry; and the water used below water-level was a mixture of quick-lime and clayey alluvial

earth, finely ground and well mixed. Above water-level the mortar used was common lime mixed with sand, and some artificial pozzolano. The lock-gates were of wood of ordinary construction, but the sluice doors were never made according to the intended design, which was deemed expensive: vertical bars or needles, were substituted for them.

No foreigners, or European machinery of any sort, were employed in the whole work; the native labourers were educated to their work under Linant, and the native appliances, katuas (baskets), shadufs (beams) and tabuts (Persian wheels) were employed. During the absence of Linant, a spring of water burst in during the excavation of the foundations at a depth of eighteen feet below ordinary low water. The Nile then began to rise. The following year the spring was built round and enclosed in the shape of a pier, and the masonry work was commenced. The excavation amounted to about 15 200 000 cubic feet; the masonry, including rubble, ashlar, and brickwork, 1 766 000 cubic feet; and the cost £40 000, or about double the estimated cost, which was enhanced by delays. When the regulating dam and new channel were perfectly ready, the old channel of the Bahr Shibiń was closed by an earthen dam, joining the wing wall of the masonry dam, and pitched with rubble facing. The whole remained in perfect order till 1873, and preserved the provinces of Menufiah and Garbiah from the effects of flood. More than half the dry season irrigation in those provinces is supplied through the Bahr Shibiń Canal, whose summer discharge is 700 cubic feet per second, and length 85 miles. It reaches the sea at Achetun.

The Bahr Shibiń has, however, a very strong tendency to silt up. One off-take silted up, another was made higher up at Mit Afifi, which also silted, and was abandoned. The amount of annual clearance is very large and is a serious drawback.

2. *The Baguriah Canal*, the next largest of the old perennial canals, of the two Middle Deltaic provinces, has an off-take with great natural advantages; it carries little silt, and seldom requires any clearance. Its discharge is 212 cubic feet per second in the low-water season.

3. *The Manufiah Canal* appears to be a modern large Deltaic canal, having its off-take at the Delta head, and alimenting several

of the here-mentioned Deltaic canals of Manufiah and Garbiah. Details of this canal are not given in the official statistics received. But it was certainly commenced by Linant about or before 1847. (*See* Linant, p. 470.)

4. *The Sahel Canal* is also a canal of the province of Garbiah, watering the districts of Jafiri, Zaflah and Mahallah; its length is 79 miles, and its surface of water 1 436 acres; further details are not available.

5. *The other four small* perennial canals of the Deltaic provinces, namely, the Sirsawah, the Ataf, the Messid el Khradar, and the Bekerem have discharges varying from 60 to 80 cubic feet per second in the dry season. Their off-takes are like the two larger ones, all on the Damiat branch of the Nile, whose waters are higher than those of the Rashid branch. Their overflow and drainage go to the waste lands, El Berriah, bordering the marshes and Lake Burlos.

Canals in Provinces West of the Rashid branch of the Nile.

1. *The Mahmudiah Canal.*—Mehemet Ali caused this canal to be made to supply water to Alexandria, as well as to irrigate land, and to create a navigable passage from the Nile to that town. The work was done by a forced levy of 320 000 men, supplied with picks and shovels, and rations of bread or biscuit. Its length is about 48 miles. Its course was for some distance nearly that of the old canal of Alexandria, which had its off-take at Ramaniah, and passed Zawet el Gazal on its way to Alexandria; this was small, unnavigable, in very bad order, and merely supplied the cisterns of the town during flood season; it had a winding course, in order to avoid embankment on low ground, about Malagat Diessi and the marshes near Lake Etko.

The off-take of the Mahmudiah was made at Atfah below Fuah, and much below the old off-take, so as to avoid fall in the ground, and to secure a better position for an off-take. Many of the sinuosities in the course are due to the mode of construction in those days: work was started first, the course and the design hurried into afterwards, by joining the pieces of canal made at hazard.

Much of the excavation was in mud, some in rock; parts in

embankment riveted with masonry extended for about 8 miles. It is said that 360 000 men were employed on it. The supply of the Mahumdiah was increased by water collected in the lowlands of Malagat Dieschi, which thus served for storage.

At Atfah there was originally no rock, and merchandise was transferred into other boats at that place for many years; but in 1842 a lock for navigation was made at Atfah and another at Alexandria, where it debouches in the Old Port, after a course of 47 miles.

The course from Atfah to Zawat el Gazal soon silted up; a fresh off-take was then made higher up, but this new reach shared the same fate. An additional supply was then obtained from the Khatatbah Canal, whose off-take is about 30 feet higher than that of the Mahmudiah at low water; thus a navigable depth in the Mahmudiah could always be secured. The defect of this arrangement consisted in the enormous quantities of silt and earth brought from the temporary earthen dams of the Khatatbah. Dredging was adopted to mitigate this, but with little effect.

As to irrigation, at first less than 4 000 acres of perennial (sefi) irrigation was effected by the Mahmudiah Canal; this gradually increased to 11 545 acres in 1849, for which the summer supply of the Mahmudiah was insufficient. The Khatatbah at that time had not enough water for more than 20 000 acres of perennial irrigation, while the direct demands on it were equal to those on the Mahmudiah, besides the indirect supply through it.

In 1849, Moujel and Arnaud set up steam pumps at Atfah for augmenting the summer supply of the Mahmudiah Canal from the river. These only effected one-tenth of the intended results; yet they served to keep up the navigation with difficulty. The perennial irrigation was gradually nearly doubled; and the supply of the Khatatbah was largely employed in cotton cultivation; besides, the series of cisterns in Alexandria were allowed to fall out of use. Hence, not only was navigation on the Mahmudiah nearly impracticable, but in 1869 and 1870 the water supply of Alexandria failed.

2. *The Behera Canal*, having an off-take at the head of the Delta, was completed soon after 1872. It was intended to supply the whole of the Behera province, and remedy the shortcomings of the Mahmudiah and the Khatatbah Canals.

The details of this large canal are not given in the official reports, but it appears that as early as 1847, Linant was employing 80 000 men on the construction of this canal, and the Manufiah and Sharkiah Canals (p. 470 of Linant).

The length of the Behera Canal was given as 26 miles, and its amount of earthwork at 353 million cubic feet in the official returns for 1873.

3. *The Khatatbah Canal.*—Some information about this canal has already been given under the head of Mahmudiah Canal, as the latter canal is supplied by the former.

The Khatatbah has its off-take near Benesalamah and Abu Neshabah; its length is about 82 miles, and it waters the Behera province, in flood as well as in the dry season. Its chief branches are the Amin Aga, and the Abu Diab, but these act mostly in the flood season. There are several permanent dams on the Khatatbah, as well as the temporary dams of earth and straw that cause so much harm in silting up this canal, as well as the Mahmudiah.

Other Works of Irrigation.

Moujel's Dam.—Muhammad Ali having noticed that the closing of the Pharaoniah Canal did not augment the supply in the Damiad branch of the Nile, but that the Rashid branch was receiving more supply than before through the Chabagan and Darawah cross channel, wished to construct a dam at the head of the Delta. His notion was to close the supply to the Rashid branch entirely, and to divert the whole of the Nile into the Damiad branch, from which all the Deltaic canals take their supply. He thought that he would then be able to introduce a perfect sheet of perennial irrigation over the whole cultivable surface of Lower Egypt, that is, over 3 800 000 acres, of which, at that time, only 2 150 000 acres were irrigated in flood, and very little in the dry season. In 1833 he gave orders that this should be done, but, on the advice of Linant, modified his intention, and ordered a regulating dam to be made across the whole of the Nile at the head of the Delta. A committee was then appointed to consider the matter, and it was then proposed to carry out the intention, and to supply from above dam three large canals—the Sharkawah Canal for the provinces east of the river, the Manufiah Canal for the Deltaic provinces, and the Behera Canal for the western provinces of Lower Egypt.

After six months of preliminary work with 1 200 forced labourers, without bread, lodging, or tools, arrangements were made under which the foundations of the dam began in earnest under the direction of Linant, the general design of the superstructure not having been worked out. Some difficulties were also caused by Court intriguers. In February, 1835, the works were suspended on account of a plague. In July, 1835, Linant had completed and delivered a complete series of plans for the dam and works connected with it; but intriguers seem to have influenced Muhammad Ali against the proposed works, and his attention was also diverted to political matters and war in Syria. The works came to a standstill. In 1837 a committee on the proposed dam was appointed; yet, contrary to their recommendation, Muhammad Ali declared that he did not want a dam. In June, 1842, Moujel, a French engineer, who had been employed in making a dock at Alexandria, had induced the Viceroy to order Linant to deliver to him all his plans and documents relating to the dam. Moujel then drew up a modified design, sent it to Paris, and obtained the report of a council of French official engineers on it in January, 1843. The opinion expressed was generally very unfavourable; yet the Viceroy very soon ordered Moujel to begin the works.

An interval of eight years had thus elapsed, and the works were to be recommenced on a fresh design and under new control.

Some of the chief differences between the two designs may be noticed.

1. The estimate of Linant put the complete cost at £840 000, while the actual cost of that of Moujel had, in April, 1853, amounted to £1 680 000 before completion, without any allowance for the forced labour that had been employed.

2. The general dimensions of the dam (and its passages) as designed by each, are about the same: the heights above datum level, &c., correspond, but the piers in Linant's design were wider.

3. The position of Moujel's dam is rather above the dam of Linant, and has not the same advantage, namely, of having old and firm soil under the foundation; but the distance between the two actual dams on the branches is less.

4. The works of Moujel in the actual river beds required European skilled labour and management, while those of Linant,

to be executed in a bend, followed by a diversion, could be done by natives.

5. The width of Linant's foundations was nearly double that of Moujel; but in some respects the arrangements of the former appear to have been defective in the original design.

6. The up-stream and down-stream shutters of Linant were coupled, to balance the water-pressure. The sluices of Moujel were complicated, and depended on the action of compressed air.

In June, 1847, Moujel commenced putting in concrete for the foundation of the dam on the Rosetta branch, hoping to finish it at low-water season; he was also hurried in the work by the peremptory order of the Viceroy. This alone was, perhaps, sufficient to account for much of the defective work; in addition, the low-water level in 1847 was about three feet higher than that of the year before.

It seems that much of the concrete thrown in on the sandy, shifting bottom never set properly; the dredging was, perhaps, never carried to a sufficient depth in some places, while the excavated soil was heaped up on both sides, close to the exterior edges of the foundation, to a height of 26 feet, causing pressure and serious slips. An attempt was made, by crowding men on the works, to remove the excavated soil to a distance; but this seems to have been either ineffectual or too late. The concrete foundations had probably been already forced up in some places. Besides, in the deeper parts of the bed, the lower part of the foundations were made of random stone thrown in to settle, and on this the concrete course was set on a level with that in other parts, where it rested on sand. If this was the case, it was a very gross error: sure to involve uneven settlement, or undermining in some form, for which Moujel cannot be excused; unless he had been already worried out of his senses.

There yet remained one possible error to be made, and Moujel was forced to make this: the superstructure of piers was commenced before the foundation was finished, under peremptory orders.

In March, 1852, Abbas Pasha wished to abandon the works. In April, 1853, a committee was appointed to examine them on the departure of Moujel. In spite of the then fully known

defects in the foundations, the piers, arches, and superstructure generally, including the sluices, were continued under Mazhar Bey. The damaged portions became gradually worse.

In November, 1861, a committee appointed to examine the works recommended that the foundations should be rendered perfectly secure, that a diving-bell should be used, and that the sluices should not be closed until the foundations were in a perfectly sound state, especially the part in random stone.

In 1863 another commission made recommendations to the same effect; but they were not carried out. In 1865 a diving-bell arrived, but it was left unused for a long time; when, at length, an attempt was made to use it, it was useless for immediate work, and required repair.

Finally, in spite of these repeated warnings, the sluices were closed against a rise of about 5 feet of water; and this completed the mischief.

In the flood of 1867 it was discovered that nine piers and nine arches were cracked, also that this portion of the dam had moved slightly down stream, detaching itself from the rest. There was also a movement near the large lock, where the foundation had been made on random stone.

The expenditure on the works, with the loss of interest on the capital at 10 per cent. during so many years, combine to form an enormous loss.

Linant did not, in 1873, despair of putting Moujel's dam in good order; but recommended an expenditure of one million sterling more, to reconstruct the defective parts of it.

The history of this dam reminds one of the ancient story of Job: an honourable man, with many opposers, was here replaced by an honourable and skilful man with the bureaucratic opposition of the infallible French Ponts et Chaussées, who set up Moujel. The same story has been repeated in India very often, terminating in the expulsion of Job. Yet in Egypt under a despotism, Linant was less severely treated; though doubtless accused of want of tact and superseded, he was not entirely ousted from service in Egypt.

IRRIGATION.

The General conditions of irrigation in Egypt, described by Linant, are of two sorts: first, that from floods, and through canals, channels and watercourses supplied by flood water only (nili); secondly, the perennial irrigation, or dry weather supply (sefi), through canals having their off-takes below low water level of the river.

The former is ancient; the latter, as far as known, is entirely modern, and due to the introduction of cotton cultivation. The superimposition of the latter on the former, though adding to the amount of cultivation, is supposed to be disadvantageous generally, causing deterioration of the soil, and injuriously altering the old conditions of the river channels. These results are gradual, and if not counteracted will eventually produce serious harm.

Flood irrigation in Upper Egypt.—As the channel of the Nile is in a slightly elevated ridge, formed by its own deposits, its floods pass over its banks and water the land on both sides, passing off in watercourses beyond. For convenience in taking off and in retaining this water on the land to the west of the river, where the breadth of cultivation is greater, a series of dykes with openings in them have been made, which probably have existed for ages. There is a long dyke along the river bank and another along or near the desert edge; there are also large transverse dykes between them. The irregular rectangular basins thus formed are of different sizes, the largest being nearly 40 000 acres in extent; but some of them are sub-divided again by dykes placed lengthwise, to separate the higher land near the river from the lower land near the desert.

Almost all of them have special channels of supply, which have their bed level at 10 to 12 feet below the lands and the flood level; which is also about 10 to 12 feet above summer level of the Nile. The bed levels of these channels are so arranged as not to receive any heavy silt from the river, but

merely the light suspended fertilising matter. They are hence supplied only after sufficient rise in the river; sometimes one channel supplies several basins successively, there are then regulators at the intermediate dykes. Ordinarily, after one basin is filled, the water flows off through sluices in the dykes in the natural water-courses away from the river, as the Sohagiah and Bahr Yusuf; but the supply may be reduced by flow either to these watercourses, or towards the Nile at will; as there are also outfall sluices leading to it, near the lower corner of the basin along the river course. On the east bank of the river the basins are all detached, as the high ground comes close to the river in several places.

In the event of a very high flood of long duration, it is impossible to discharge water from a basin into the river at any required time; it may then be compulsory to allow water to remain late on the lower part of the basin; worms are then bred which destroy any grain sown and spoil the crop. If the flood be low and late, some water may remain late in the lower lands of a basin; if this is eventually passed off into an inferior basin where sowing has begun, the sowings are thus spoilt by the second watering supplied in this way.

The land west of the Bahr Yusuf is also divided into flood basins watered from it, from its off-take down to the Illaun Gorge, where it enters the Fayum. The flood channels (or nili canals), before mentioned, diminish gradually in depth, their beds terminating by arriving at ground level of the last land to be watered from them; their falls are hence dependent on the two conditions: first, of starting from the river with a bed level about 13 feet below land at that off-take; secondly, of ending at ground level on the last field to be watered; these conditions both depend on the fall of the land. The details of these cases would not be valuable, for they do not seriously affect the supply.

Flood irrigation in the Fayum.—The flood water of the Nile is almost entirely supplied to the Fayum through the Yusufi or Bahr Yusuf channel which enters the Fayum through a regulating dam at the Illaun. (For details of its course, see under Bahr Yusuf, among *Canals*.) But this dam connects two dykes one directed to the S. W. joining the Sediment Hill, the other to N. W., to Gisrat Gadallah, and this latter also has sluices towards

Fayum, for drawing off excess of flood water from the next northern basin down the Nile Valley, in which water is retained by the large Koshekah dyke. The flood supply to the Fayum is plentiful; the land is divided into basins formed by dykes, and smaller sluices and susidiary channels supply the different parts of it. The level of the land varies greatly; it is generally a large depression or basin, whose lowest part is occupied by Lake El Korn, or Birkat Kerún; the rest consists of three plateaux, successively lower from the sill at the Illaun Gorge down to the lake, the whole difference of level is about 203 feet, but the lake is below sea level.

Flood irrigation in Lower Egypt.—The general mode is the same as in Upper Egypt, and has been so, certainly since 1823. The floods, coming down the two branches of the river in the Delta towards Rashid and Damiad, overflow the banks and spread over the land; which is divided into large inundation basins by dykes at right angles to the course of the river. The overflow or drainage from these basins takes different courses, forming the permanent drainage channels of the Delta, and of Lower Egypt to east and west of the two branches. These discharge into the various large lakes and swamps near the coast. It will be noticed that everywhere the irrigation effected by floods under this system supplies light fertilising sediment to the soil, thus maintaining its productive power; while heavy deleterious silt, resulting from local scour in the river channel, &c., does not interfere with either the channels of flood supply (canals nili) or with the land. The crops of the flood season are generally wheat, beans and barley; in the north part of the Delta rice is also grown as a flood season crop.

Perennial Irrigation.—Although there was doubtless some perennial irrigation in Egypt in ancient times, the amount of it was probably small, and it was obtained entirely by lift, with such appliances as chains of pots, beams, and buckets, &c. A strictly perennial (or saifi) canal, drawing a supply from the Nile in its low stage, and supplying land direct from it by flow, is comparatively modern; dating from the introduction of cotton-growing, by Jumel and Maho Bey in the time of Muhammad Ali.

The earlier perennial canals have their off-takes at a level 3·5 to 4·5 feet below mean low-water level of the river; most of

them, especially those from the upper part of the valley, are dug to about 28 feet below ground level at their commencement; their depth diminishing gradually until their beds arrive at ground level at the furthest land to be watered. Their courses are very long, so as to carry water as far north as possible. Their falls are less than that of the river at low water, and are hence very gradual, as the object is to water without any need of lift; but one result of this very slight fall is that the discharge is small, particularly so in unusually dry seasons.

They serve chiefly for watering cotton, rice, and sesamum, also maize; the sowing takes place at the end of April and the beginning of May; the watering from them continues until July, or till flood season begins. The clearances of their channels and off-takes, which are loaded with heavy, coarse silt, also are effected between April and flood.

The ordinary mode of watering land from these perennial canals is to block the passages in permanent dams, or to build small temporary dams in the canals at various distances apart, dependent on the fall, and thus raise the water level in them up to the level of the land to be watered. The land is then watered through simple cuts in the canal banks; and the silting up of the channel seems to be disregarded. In places far above the first dams, and on the banks, the water is obtained by lift from the canals, from the river, and from collecting shafts.

Some crops are, however, not watered continuously; as cotton baali, which is watered perhaps only twice after sowing in the beginning of May, and may remain unwatered to the end of June; it then receives a plentiful flood supply; the resulting crops are of course scanty. In better cases the crops receive about half the fully suitable amount of watering.

The full amount would be one cubic foot per second to 120 acres generally, or to 100 acres when rice alone is grown, at this season.

Double Irrigation.—However beneficial the effect of growing dry season crops may be to Egypt, it is needful also to notice the effects of superimposing perennial irrigation on land irrigated in flood. The primary or flood basins of the land have parts divided off in them by dykes for perennial basins of irrigation; these dykes keeping out the flood waters that are mostly not wanted; that is to say, apart from half season crops. Hence the amount of

flood water utilised has been much decreased since olden times. The results are that the drainage channels of the region carry off less water; the old flood canals are less used, less filled, and become unnavigable; and the river channels are filled in flood to a very high level. Also the land from which the floods are shut out loses the fertilising silt it would otherwise get, and the soil thus deteriorates greatly by gradual exhaustion.

Besides, though the flood water may be shut off from the surface, there is yet a certain amount of infiltration from below which may produce efflorescence in the dry weather, and spoil the soil; for almost all the land is impregnated with salts of some kind. If the land is thus allowed to remain unflooded for several years it become sterile.

The use of old manure from ancient ruins for hastening maize crops, and clearing the land before the Nile becomes too low for convenient watering, increases the before-mentioned tendency to sterility; for that manure contains salts in abundance. The natural remedy is to flood and wash the land, as well as to drain it well; but this involves loss of the crops of the season, and perhaps of the whole year; hence it is perpetually deferred.

[For the perennial crops of cotton, maize, and rice sown in May, June, or even sometimes much later (in August), are harvested during the flood season.]

Last, the introduction of perennial canals has involved an enormous amount of needful clearance of silt, annually; while much of the cleared silt is washed back again by the next flood or two. The amount of annual clearance necessary is given in the tabular statement or list of perennial canals. At a rough estimate, it is the removal of 500 million cubic feet to a distance of 200 feet, and to a height of perhaps 40 feet. When effected by manual labour, it is the loss to the population of 60 days' work, besides coming and going; for the average day's work, in wet silt, under the conditions of the case, does not exceed 18 cubic feet, though in the upper or dry silt it is 24 cubic feet; and some of the districts are unable to supply enough men for the clearance of the canals supplying their own district.

Even if steam power be used during the available four months of the year, the annual expense would be about half a million pounds sterling for the clearance of the perennial canals of Lower Egypt alone.

There is no doubt that much of the silt difficulty is due to the use of temporary earthen dams in the perennial canals; but even if the large expense be incurred of building the large number of masonry or brickwork regulating dams necessary to replace them, the evil would merely be mitigated, not removed; for wherever a current is checked, silt will fall.

Remedies.—While there are many and conflicting views as to the best possible means of extending perennial irrigation in Lower Egypt—whether by a dam at the Delta head, or by a large, long canal with headworks opposite the Fayum, or by enormous expense in steam pumps—it may yet be considered whether perennial irrigation, strictly as such, and on a large scale, is absolutely necessary to Egypt. A moderate amount of it might suffice. As for the rest, in the form of anything to replace the hitherto wished-for remainder, it is very possible that the remedy may be arrived at by some new agronomic development of half-season crops, or early and late crops of produce of selected suitable sorts. Good gardening, training, and agricultural management of an advanced type could doubtless supply this development. There are at present some half-season crops grown in Egypt, and there is no apparent reason why skilful gardening may not introduce many more. Such crops could be supplied with a moderate amount of water from the Nile in its intermediate stages only, and the expense of so doing would be comparatively small, as the lift would be less everywhere, the silt difficulties would be very greatly reduced, and the various anticipated contingencies dependent on the larger strictly perennial schemes would cease to become subjects of dread and of dispute.

Perhaps this suggestion may be utilised to the benefit of the Egyptian people.

THE CHIEF CROPS OF EGYPT, ESTIMATED FOR 1871, ACCORDING TO ISMAIL

Chief Crops.	Month of Budding.	Month of Flowering.	Month of Fructifying.	Amount of Produce. Upper and Middle Egypt. Cubic feet.	Amount of Produce. Lower Egypt. Cubic feet.	Amount of Produce. Total All Egypt. Cubic feet.
Wheat of Upper Egypt ...	1-2	2-3	3-4	6 863 717	1 000 000	21 283 185
„ of Lower Egypt ...	1-2	2-3	3-4	...	14 419 468	
Barley of Upper Egypt ...	2	3	4	2 747 059	...	*14 602 280
„ Lower Egypt ...	2	3	4	...	11 855 221	
Maize Saifi	4	5	6	4 066 335	12 681 655	18 520 069
„ Nili	7	9	10	114 555	1 658 524	
Sorgho, summer	4	5	6	...	...	not given.
„ winter	7	9	10			
Rice	...	...	...	0	464 212	464 212
Beans of Upper Egypt ...	12	1	2-3	6 348 230	...	12 944 813
„ Lower Egypt ...	12	1	2-3	...	6 596 583	
Lentils	1	2	3	1 318 044	131 404	1 449 448
Lupins	1	2	3	106 659	77 238	183 897
Peas	2	3	4	160 874	58 891	219 765
Clover† Egyptian	12	1-2	4	873 810	356 314	1 230 124
„ Hijaz	1-2	5-11	8-11			
Sesamum	6	8	10	525	25 326	25 851
Hemp	...	...	...	4 200	0	4 200
Linseed	11	2	3	49 847	113 841	163 688
				Centals.	Centals.	Centals.
Flax	„	„	„	8 270	33 786	42 056
Cotton	3	5-9	9-11	70 163	1 936 300	2 006 463
Sugar Cane...	1-12	0	1	1 527 100	158 247	1 685 347
Tobacco	12-2	5	6	16 366 incomplete	3 055 incomplete	19 421 incomplete

Other crops are garden produce, halfa, dyes, drugs and fruit trees.

* Shows error in the original. † In excess of pastured fodder.

The radeb or cubic cubit is nearly 7 cubic feet English.

SADIK PASHA; WITH DETAILS OF SUGAR CANE AND COTTON CROPS.

Mudiriah.	Sugar Cane Cultivation. Domain Lands.	Sugar Cane Cultivation. Private Lands.	Sugar Cane Cultivation. Amount of Produce.	Sugar Cane Cultivation. Yield per Acre in Centals.	Cotton Cultivation. Private Lands.	Cotton Cultivation. Amount of Produce.	Cotton Cultivation. Yield per Acre in Centals.
	Acres.	Acres.	Centals.		Acres.	Centals.	
Esnah	5 018	18½	148	8	...	85	...
Kenekossir	0	2 182	163 950	75	...	...	...
Girgah	0	183½	4 587	25	...	...	...
Assiut	10 000	25	500	20	...	...	...
Miniah & Benimazar	31 356	26 287	1 182 915	45	...	...	...
Benisuef	2 397	35	...	...	26	78	3
Fayum	6 010	5 000	175 000	35	20 000	30 000	1½
					...	*40 000	...
Upper & Middle Egypt	54 781	33 731	1 527 100		20 026	70 163	
	Acres.	Acres.	Centals.		Acres.	Centals.	
Gizah	193	...	...	...	...	...	5¾
Galliubiah	...	440	93 060	211	32 110	68 240	2⅛
Manufiah	...	411	61 779	150	72 939	218 917	3
Sharkiah	...	285	...	...	125 000	437 500	3½
Garbiah	...	284	3 408	12	237 258	711 744	3
Dakkaliah	...	500	...	...	126 933	380 799	3
Behera	...	134	...	...	64 731	119 070	1¾
Lower Egypt	193	2 054	158 247		698 971	1 936 300	
All Egypt	54 974	35 785	1 685 347		718 997	2 006 463	

The English cental of 100 lbs. is nearly the Kantar.

IRRIGATED CROPS.

THE PRODUCTIVE VALUE OF LAND IN EGYPT.

(*From a Memorandum by* MR. NICOLSON, *Cairo, April,* 1883.)

The gross productive value of an acre of the richest land in the most fertile province, based on rotation crops for a period of three years, varies between £6·85 and £9·60, average £8·38. The radical difference between these results lies in the estimated amount of cotton produced per acre, for as to the value of other crops raised per acre the differences are small. If the average return of cotton per acre be taken at 5 centals (of 100 lbs.), the data corresponding to the above would be, for extremes £8·60 and £9·60, average £8·99 for the best land.

The rotation of crop would be—1st year, cotton and bersim (clover); 2nd year, dura (maize) wheat, and bersim; 3rd year, dura, beans, and bersim.

Cotton is the most valuable crop; in some rare instances as much as 7½ centals per acre have been produced in one year. For this the ground is prepared in September, the sowing takes place in March, and the gathering in October. A crop is raised only every third year.

Bersim is cultivated as fodder. Two cuttings may be obtained in a year, but the second is often allowed to die in the ground, as it possesses great recuperative power.

Taking the gross productive value of an acre of rich land in the Delta at £9, it appears, from the examination of statistics, that the net value of the produce is an interest of 9½ per cent. on the capital. The actual value of an acre varies greatly. It is, in some cases, as high as £60 or £70. On the Domain lands the average value of an acre is £12 in Upper Egypt and £20 to £25 in the Delta. A large landowner in Upper Egypt estimates the value of an acre there at £20, and states that, under sugar and maize, it would give 6 per cent. interest, and under other crops, 2½ per cent.

The following table shows the letting value of Domain land, per acre, and the extremes of rent in various provinces :—

Province.	Teftisha.	Lands.	Acreage.	Lowest Rent per acre.	Highest Rent per acre.	Taxes.
				£	£	£
Assiut	Beni Rafa ...	Beni Shokir	604	1·85	—	1·23
		Tataliah	32	—	3·35	1·47
Benisuef ...	Achment ...	Bahbashinah	90	5·00	—	0·14
		Tezment	80	—	6·00	1·20
El Fayum...	El Fayum ...	The whole	46 139	—	1·08	0·31
Gizah	Bedrashin ...	The whole	12 228	—	2·70	1·31
Galliubiah	Shubra	Birket	32	0·50	—	0·52
		Shubra	120	—	6·18	1·49
Sharkiah ...	Abu Kebir	Abu Kebir	48	0·45	—	0·71
	Tel Hawin	Tel Hawin	24	—	5·30	1·02
Dakkaliah	Tommay ...	Zafar	40	0·36	—	0·29
		Karmut	690	—	5·35	1·20
Garbiah ...	Dokmera	Kadmiah	205	0·10	—	0·25
	Safiah......	Nosfaul Chabas	44	—	10·18	1·62
Behera	Dessunes ...	Kardud	135	0·06	—	0·17
		Bissentawai	36	—	6·50	1·03

The taxes are paid by the landowner in all cases.

The gross value of an acre under rice cultivation varies from £5·65 to £8·00. The expenses of growing rice are very heavy. In the rice districts wheat and maize do not grow readily, though barley can be produced, and cotton serves as an alternative crop.

The gross value of an acre of sugar cultivation in Upper Egypt is £18·75.

An estate of 100 acres of rich land in the Delta furnishes the following details as an average yield yearly in three years cultivation :—

		Total.	Per acre.
Maize	£130	£875	£8·75.
Wheat	£165		
Beans	£ 80		
Cotton	£500		

The acre was here valued at £40, and the net produce showed an interest of 9½ per cent.

THE PRODUCTIVE VALUE OF LAND IN EGYPT.

(*Extract from the Report of* M. SUAREZ, 1883, *from personal experience in the province of Garbiah.*)

The tenure of land in Egypt is divided into three classes—large holdings, medium holdings, and small holdings; they are all worked differently.

1. In large holdings the landowner manages his estate through inspectors and agents. The labourers receive daily in money £0·02 per man, and £0·015 per child, and in kind a quarter of the nili maize crop, besides allowing each fathe . family an acre of land for support of himself and his cattle, . a rent equal to the taxes on it. The landowner supplies irrigating machines, but utilises the manure of the labourer's cattle.

2. In medium holdings there is a joint arrangement with the labourer. The landowner incurs the taxes, expenses of irrigation, seed, implements, and material. The labourer supplies labour until the harvest, when he receives one-fifth of the summer (sefi) crops, cotton and legumes; one-fourth of the nili maize crop, but no part of the (chatuwi) winter crop. The collection, preparation, and storing of the crops is charged to the landowner. The labourer has an acre for clover, and supplies manure from his cattle as in the former case.

There are also other modes of division which a less usual.

3. In small holdings the labourer is his ow ndlord. He cultivates his own land with the help of his w. d children, and incurs all the expenses of production. Such holdings are the most numerous, and yield the greatest return.

Rotation of Crop.—As there may be crops of three sorts in the year—the chatuwi (winter), the sefi (summer), and the nili (intermediate)—it must be noticed that the land employed for a nili crop will afterwards yield a sefi crop; also that if there be a want of water in the sefi, or dry season, there cannot be a sefi crop. But as this report deals with the best land, where irrigating machines are employed for two months in the year, it is presumed that water is available, and every arrangement for securing good crops is made.

If the sefi and chatuwi crops were alternatively grown each year on the same land exhaustion of the soil would result eventually; hence the following arrangement of rotation, over

three years, for an estate of 300 acres, is the mode usually adopted. The 300 acres are divided into three portions, A, B, and C, of 100 acres each, worked correspondingly and in rotation in each period of three years, thus—

First Year.

	Acres.	Acres.
Maize (nili), Clover (nili), Cotton (sefi)		100 A
Wheat (chatuwi)		100 B
Beans (chatuwi)	50 C	
Clover (chatuwi)	25 C	
Allotment to labourer for clover	25 C	
		300

Second Year.

Beans (chatuwi)	50 A	
Clover (chatuwi)	25 A	
Allotment to labourer for clover (chatuwi) ...	25 A	
Maize, Clover (nili), and Cotton (sefi)		100 B
Wheat		100 C
		300

Third Year.

Wheat (chatuwi)		100 A
Beans	50 B	
Clover	25 B	
Allotment to labourer for clover	25 B	
Maize, Clover (nili) and Cotton (sefi)		100 C
		300

Some minor details require explanation, in order that the following detail of expenses may be clear. They are these :— 1. The clover (nili) or baali is sown among the maize, half at a time, to secure succession of crop ; the second half hence alone has to be watered after the maize is cut. 2. In the chatuwi harvest there are 160 acres to be harvested, out of which 10 acres are of clover reserved for seed. 3. Cotton stalks, used as fuel for the pumping machinery, are estimated by the hemlah, which is about the fifth of the yield of an acre. The hemlah is equivalent to two centals of coal, and is sufficient for one watering of two acres of land.

Assuming successively the three conditions of tenure before explained, and this rotation, the expenses and income will be

thus in detail for 300 acres of the best land. The reductions have been effected on the approximate basis of taking a feddan as an acre, and 100 piastres at £1 sterling; the error in the former being about ¼ per cent., and in the latter 2½ per cent., both in diminution of average values commonly used.

GENERAL EXPENSES ON 300 ACRES.

		£
Taxes on 300 acres at £1·64 per year		492·00
Fixed salaries and wages: monthly—		
One inspector, 1 manager, and 1 clerk	£5·5	
Four cattle-drivers	3·0	
Three watchmen or caretakers	1·8	
For 12 months at	10·3 =	123·60
Seed—		
Maize (nili) for 100 acres, 147 cubic feet at ...	£0·086 =	12·60
Clover (baali) „ „ „ ...	0·214 =	31·45
Clover (meshawi) for 25 acres, 44 „ ...	0·214 =	9·42
Cotton for 100 acres, 111 „ ...	0·107 =	12·75
Wheat „ 100 „ 350 „ ...	0·136 =	47·50
Beans „ 50 „ 233 „ ...	0·121 =	28·33
		142·05
Lift of water during 2 months—		
One mechanic, 1 stoker, and 2 labourers...		9·00
Fuel, cotton stalks for 6 waterings of 100 acres at the rate of £0·10 for 300 hemlahs		30·00
Fuel, cotton stalks, for 4 waterings of 50 acres, at the rate of £0·10 for 100 hemlahs		10·00
Oil, 90 pounds, at £0·013 = 1·572; Grease, 60 pounds, at 0·021 = 1·350; Rags, &c., for cleaning 1·000 = 1·		3·92
		52·92
Food of Cattle during 4 months—for 20 oxen, 3 camels, and 7 mules or donkeys.		
Beans, 688 cubic feet, at £0·85 = 83·93; Straw, 80 hemlahs, at 0·10 = 8·00		91·93
Total general expenses		£902·50

Wages of Labourers

		£
Two men preparing manure for 8 months at ...	£0·040 =	9·60
Two lads for moving manure, &c. , „ . .	0·015 =	7·20
Spreading manure on 100 acres	0·080 =	8·00
		24·80
On watering the second half of 100 acres of clover (baali) } 25 days' labour at ...	0·02	0·50

For clover (meshawi and tashif) of 25 acres—

Labour on 25 acres—2 men per acre at £0·02 ...	1·00	
Sowing of „ „ ½ man „	0·24	
Eight waterings „ ½ man „	1·92	
		3·16

Wages expended on the Cotton crop, 100 acres—

	Days' Labour.	
First preparation of land, 3 men per acre ... =	300	
Second „ „ 2 men „ ... =	200	
Third „ „ 1 man „ ... =	100	
Tashif, or breaking clods	20	
Takhrit, or trenching, ⅓ man per acre ... ... =	33	
Tracing, or setting out land	4	
Takhrit, in water-channels, 3 men per acre ... =	300	
First watering ... ... ½ man per acre ... =	50	
Nine waterings ... ... ⅓ man per acre ... =	297	
£0·02 per man for	1 304 =	26·08

	Days' Labour.	
Sowing... ... ... 3 men per acre	300 =	6·00
„ 0·015 per lad ... 3 lads per acre	300 =	4·50
Thinning the crop ... 2 men per acre	200 =	4·00
Weeding—4 times ... 4 men per acre	400 =	32·00
Four watchmen for 2 months at £0·60 per month		4·80
		51·30

Labour under Contract.

Gathering cotton—500 centals at ... ...£0·15 =	75·	
Gathering stalks—100 acres at ... ... 0·25 =	20·	
Managing channels	10·	
		105·00
		£210·84

			£
Carried forward			210·84
Wages expended on Wheat crop, 100 acres—			
	Days' Labour.		
Preparing land twice	200		
Levelling in plots and sowing	200		
First watering	50		
Second watering	33		
Two watchmen for a month	60		
£0·02 per man for	543	=	10·86
Wages expended on Bean crop, 50 acres—			
	Days' Labour.		
Preparing land	50		
Sowing	37		
Levelling in plots	50		
Two waterings	50		
Two watchmen for 2 months	120		
£0·02 per man for	307	=	6·15
On the chatuwi harvest, 160 acres—			
	Days' Labour.		
Threshing—10 men per acre	1 600		
Watching barn-floors—2 men for 4 months ...	240		
£0·02 per man for	1 840	=	36·80
Miscellaneous Expenses:			
Unemployed cattle—3 at £20	£60		
Implements and repairs	30		
			90·00
Total expenditure on labour			354·65
General expenses before given			902·50
Total expense			£1257·15

Or about £4·19 per acre.

GROSS INCOME FROM 300 ACRES.

	£	£
From maize (nili) 100 acres at 35 cubic feet ... =	3 500	
Less one-fourth for labourers, and a deduction for carriage of $\frac{4}{5}$ per cent.	896	
or at a price of £0·0857 per cubic foot	2 604 =	223·20
From clover (baali) grown with maize, and sold green, 100 acres at £1·50 ... ... =		150·00
From uncleaned cotton, 500 centals, at £3·20 ... ... =		1600·00
From wheat, 100 acres at 35 cubic feet	£3 500	
Less deduction for carriage of $\frac{4}{5}$ per cent. ...	28	
or at a price of £0·133 per cubic foot	3 472 =	471·20
From beans, 50 acres at 28 cubic feet	1 400	
Less for carriage	14	
or at a price of £0·121 per cubic foot	1 386 =	168·30
From second cutting of clover on 10 acres		29·75
Cotton stalks from 100 acres		50·00
Straw, of all sorts, from 160 acres...		32·00
Rent of 25 acres from the labourer		41·00
Total gross income		£2765·45

Or £9·22 per acre.

Total expense	£1257·15

Or £4·19 per acre.

Total net income	£1508·30

Or £5·03 per acre.

To estimate the return on land purchased, as rent is not included in the foregoing account, the estimated value of the best land of the State Domains of Santa, El Hayatem, and El Safia, in the Mudiriah of Garbiah, is assumed. This is fixed at a mean price of £50 per acre, including brokerage.

CAPITAL ACCOUNT (300 ACRES).

300 acres of land, at £50 per acre	£15 000
1 pump, and engine of 10 horse-power	500
20 oxen, 3 camels, &c.	481
10 ploughs, flails, and implements, carts, &c.	319
	£16 300

The return on this capital is 9¼ per cent., according to the foregoing account. But it must be noticed that the amount of cotton and its value form the principal part of the gross income.

The cotton crop may be attacked by worm, or may suffer from want of water; if it suffer from both causes, the yield is only 3·22 centals per acre; if from want of water alone, it is 5 to 6 centals; but a good crop yields nearly 7 centals; hence the valuation at 5 centals adopted is a rather low average. With improved irrigation it would certainly be 6 centals, raising the return on capital from 9¼ to 11 per cent.

2. *With medium holdings* and sharing of crop, as before mentioned:—

EXPENSES ON 300 ACRES.

	£
Taxes	492·00
Seed, as by former detail	142·05
Fixed salaries	123·60
Lift of water	52·92
Food of cattle	91·93
Gathering cotton	75·00
Miscellaneous expenses...	90·00
Or £3·55 per acre	1067·50

GROSS INCOME FROM 300 ACRES.

Gross income, as by former detail	2765·45
Less one-fifth of the cotton crop	320·
Or £8·15 per acre	2445·45
Net income	£1377·95
Or £4·59 per acre.	

This amounts to 8¼ per cent. on the capital; and as the labour is more carefully done, the yield of cotton may also be greater, in which case there is an additional advantage to both landowner and labourer.

3. *With small holdings* under peasant proprietors, worked by themselves and their families :—

EXPENSES ON 300 ACRES.

	£
As by detail in No. 2	1067·50
Clover seed for 25 acres of allotment	9·37
	1076·87
Less fixed salaries and gathering cotton	198·60
Or £2·93 per acre	878·27

GROSS INCOME.

	£	£
Maize (nili) 3 500 cubic feet, at	0·085	300
Clover (baali) 1 cutting, 100 acres at	1·50	150
Clover (meshawi) 3 cuttings, 25 acres at	3·00	75
Uncleaned cotton, 500 centals, at	3·20	1 600
Wheat, 3 500 cubic feet, at	0·136	475
Beans, 1 400 cubic feet, at	0·121	170
Second cutting of clover, for seed, 140 cubic feet		30
Cotton stalks, 500 hemlah, at	0·10	50
Straw of all kinds, 320 hemlah, at	0·10	32
Or £9·60 per acre		2 882
Expenses		878
Or £6·67 per acre net income		2 004

This represents 12¼ on the capital before estimated.

RESULTS OF LETHEBY'S ANALYSES OF WATER OF THE NILE DURING A YEAR (FOR 1874–75) GIVING THE CONSTITUENTS PER MILLION PARTS.

	8 June.	10 July.	12 Aug.	20 Sept.	12 Oct.	12 Nov.	12 Dec.	23 Jan.	12 Feb. at Dam.	March.	April.	13 May at Bulak.
DISSOLVED MATTER.												
Lime	41·67	39·92	44·22	42·60	23·09	43·04	42·64	44·68	40·57	46·31	47·63	51·78
Magnesia	16·23	51·13	10·30	6·17	4·83	11·32	9·26	10·29	8·74	9·77	8·23	10·29
Soda	12·01	7·44	5·87	3·01	5·04	3·18	3·69	3·47	3·07	5·94	8·30	13·01
Potassa	24·75	10·62	5·01	41·20	23·48	13·29	10·02	8·31	9·34	7·28	6·09	4·04
Chlorine	16·43	8·51	6·28	2·09	4·91	2·07	2·76	2·42	2·51	6·13	9·16	17·37
Sulphuric Acid	28·08	28·38	18·37	19·96	19·08	19·11	17·64	19·60	18·13	22·63	20·09	29·31
Phosphoric Acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Nitric Acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Silica, Alumina, and Oxide of Iron	7·01	7·13	11·29	12·57	18·43	9·86	8·19	8·57	7·29	12·71	7·14	6·71
Organic Matter	15·00	10·57	11·86	19·29	24·14	13·43	9·20	12·86	15·86	20·86	25·86	31·29
Carbonic Acid and loss	41·82	36·16	42·81	47·54	35·57	34·27	32·74	34·51	41·20	46·51	49·36	40·91
Total Solids	203·00	163·86	166·01	194·43	858·57	149·57	136·14	144·71	146·71	178·14	181·86	204·71
Saline Ammonia	0·057	0·129	0·043	0·100	0·071	0·064	0·049	0·087	0·048	0·036	0·035	0·014
Albumenoid Ammonia	0·114	0·100	0·071	0·171	0·143	0·114	0·108	0·143	0·116	0·086	0·107	0·118
SUSPENDED MATTER.												
Mineral	60·86	87·29	1307·43	483·43	332·14	306·86	269·71	148·99	114·86	46·29	61·14	38·29
Organic	8·29	91·14	184·14	59·14	45·86	36·86	19·43	19·14	10·86	6·86	5·14	9·43
Total Solids	69·15	178·43	1491·57	542·57	378·00	343·72	289·14	167·43	125·72	53·15	66·28	47·72

The Qualities of the Water of the Nile.—As a potable water, the water of the Nile does not stand high in quality compared with that of other great rivers; it is, however, ordinarily drunk after allowing its slime to decant, and after cooling either in wells or in porous vessels. When we reflect on the immense tract of swamp in the Ghazal region and the upper tributaries near Lake Noo, it seems almost surprising that it is at all fit to drink. As for the theory of oxidisation of organic matter during flow over long distances; in this case the immense distance and the still remaining dissolved organic matter seem to prove that any oxidisation can only be incomplete even under the most favourable circumstances.

There is, however, a period of from twenty to thirty days, when the inhabitants of Egypt avoid drinking Nile water. This period, Shat Raviat, is that of the Green Waters, and begins generally in June. The green colour of the river water is due to cellular vegetable matter, probably very thin algæ from the Ghazal marshes. These have been studied by Dr. Schnepp. The reddish waters which arrive at Cairo in July, driving out the green waters, are the results of the rising flood; which, collected in the Abyssinian torrents and streams, arrives at Khartum in May, and takes two months more to pass down to Egypt.

As the samples analysed by Dr. Letheby were probably taken once a month, independently of the twenty days of green waters, there is not any trace of them in the results of analysis.

The remarks of Dr. Letheby on his own results, are:

1. That the dissolved matters increase gradually from December to June; and diminish from June to December, excepting in September.

2. That the azotose matters are very large, compared with those of European rivers.

3. The sulphates and carbonates and chlorides of lime and magnesia and soda are not in excess; thus the water is well suited to domestic purposes.

4. The carbonates and silicates of potash are large in amount, especially in June, September and October, when the soluble constituents have most fertilising qualities.

As to the slime or suspended matters:

1. The suspended matters are the chiefly fertilising ingredients

in Nile water; these are most abundant in August and September.

2. The potash and phosphoric acid of the slime constitute the manurial value; and these are in greater proportion in the samples of August and September.

3. The high floods from August to October hence supply the qualities most valuable in irrigation.

The following is the composition of Nile slime from the same samples of water during the same period, 1874–75.

	Samples of August and September.	Samples taken later in the year.
Lime	2·06	3·18
Magnesia	1·12	0·99
Soda	0·91	0·62
Potash	1·82	1·06
Phosphoric Acid	1·78	0·57
Silica	55·09	58·22
Alumina and Oxide of Iron ...	20·92	23·55
Organic matter	15·02	10·37
Carbonic Acid and loss ...	1·28	1·44
	100·	100·

The following results of analysis of Well waters from the valley of the Nile show large proportions of sulphates and carbonates of lime and magnesia, also of alkaline chlorides. They have very little fertilising quality, and are unsuited for domestic use. They hence contrast markedly with Nile water.

CONSTITUENTS OF WATER FROM EGYPTIAN WELLS IN 1874.

Per Million Parts. DISSOLVED MATTER.	Brombel, 28th June.	Umfast, 17th June.	Steined Well at Shubrament, 3rd August.
Lime	145·93	166·81	183·94
Magnesia...	28·15	28·67	79·11
Soda	87·27	51·32	107·51
Potassa	3·48	1·99	6·57
Chlorine	72·86	81·16	254·06
Sulphuric Acid	86·73	39·20	51·94
Phosphoric Acid... ...	—	—	—
Nitric Acid	1·69	1·87	1·45
Silica, Alumina and Oxide of Iron	17·28	18·01	18·83
Organic matter	4·29	6·14	7·57
Carbonic Acid and loss...	123·61	135·40	138·88
Total Solids...	571·29	530·57	849·86

Per Million Parts.	Brombel, 28th June.	Umfast, 17th June.	Stiened Well at Shubrament, 3rd August.
DISSOLVED MATTER.			
Saline Ammonia... ...	0·057	0·043	0·071
Albuminoid Ammonia ...	0·071	0·057	0·071
SUSPENDED MATTER.			
Mineral	6·57	11·00	3·14
Organic	34·56	87·14	7·43
Total Solids ...	41·13	98·14	10.57

ANALYSIS OF EGYPTIAN TRONA, *by* PROFESSOR DUPRÉ.

Chloride of sodium	8·16
Sulphate of soda	2·15
Silicate of soda	0·29
Bicarbonate of lime	0·20
Sesquicarbonate of soda	47·29
Carbonate of soda	18·43
Water	19·67
Insoluble substances	4·11
	100·21

METEOROLOGICAL OBSERVATIONS.

At Cairo.	Mean Temperature. Mean of 1868–71.	Mean Pressure. Mean of 1868–71.	Prevalent Wind in 1871. Proportion.	Duration of Showers in 1871.	Evaporation. Mean of 1870–72.	Temperatures of Nile water at 9 a.m. in 1872.
	Fahr.	Feet of Mercury.	Direction. Per cent.	h. m.	Feet.	Fahr.
January ...	55°·13	2·4988	NE. 32	0 54	0·269	57°·76
February ...	55·00	2·4993	NW. 24	2 8	0·404	59·00
March ...	62·56	2·4862	W. 23	0 6	0·696	66·02
April... ...	68·02	2·4883	N. 28	5 40	0·823	67·10
May	79·70	2·4838	NE. 36	0	1·011	72·50
June... ...	84·18	2·4801	N. 51	0	1·008	74·48
July	85·78	2·4731	N. 79	0	0·922	78·26
August ...	84·97	2·4745	N. 99	0	0·788	80·60
September	78·51	2·4850	N. 99	0	0·597	79·70
October ..	73·42	2·4893	N. 71	0	0·443	76·10
November	65·32	2·5628	N. 58	0 20	0·286	69·80
December	59·20	2·5000	N. 31	0	0·269	64·30
Means, Totals, and Extremes	70°·90	2·493	N. 49	h. m. 9 8	7·516	70°·52

The observations supplied by Ismail Bey, Director.
The Nile temperatures were observed at the surface.

METEOROLOGICAL OBSERVATIONS.

At Alexandria.	Mean Temperature in 1872.	Highest Maximum Temperature in 1872.	Lowest Minimum Temperature in 1872.	Rainfall in 1872. Depth.	Number of Rainy Days.	Evaporation in 1872.
	Fahr.	Fahr.	Fahr.	Feet.	Days.	Feet.
January ...	57°·38	68°·90	44°·42	0·185	9	0·305
February ...	59·36	79·52	46·40	0·074	6	0·335
March ...	65·30	89·96	51·26	0·193	5	0·558
April ...	66·56	93·02	54·14	0·010	1	0·679
May	71·60	93·38	55·58	0	0	0·847
June... ...	76·82	109·04	63·14	0	0	1·037
July	78·98	97·88	68·72	0	0	1·057
August ...	80·24	86·90	70·52	0	0	1·011
September	78·98	86·36	69·08	0	0	0·804
October ...	75·38	89·42	61·88	0	0	0·702
November	69·62	84·20	54·86	0·250	6	0·473
December	62·06	76·10	47·12	0·218	11	0·423
Means, Totals, and Extremes	70°·16	109°·04	44°·42	0·930	38	8·231

The observations supplied by M. Drury, C.E.

Storms on 6 days, hail on 2 days, mist on 1 day, aurora borealis on 1 day.

CHAPTER IV.

INDIA.

RIVER BASINS, AREAS, &c.

RIVERS.

CANALS.

STORAGE WORKS AND WATERWORKS.

RECLAMATION AND PROTECTIVE WORKS.

IRRIGATED AND ORDINARY CROPS.

WATER RATES AND TOLLS.

ANALYSES OF WATER, SOIL, ETC

INDIA.

AREAS OF THE VARIOUS PROVINCES AND TERRITORIES ACCORDING TO OFFICIAL ACCOUNTS.

Provinces and Territories.	British Administration. Sq. miles.	Native Administration. Sq. miles.	Total Square miles.	Population in 1881.	Under British Admin. Per cent.
I. NORTH-WESTERN INDIA.					
The Punjab	107 010	104 958	211 968	23 646 620	80
Sind	48 014	—	48 014	2 413 823	100
Khairpur	—	6 109	6 109	129 153	0
Khelat	—	unkn.	unkn.	unknown	0
Rajputana	—	129 750	129 750	10 268 392	0
Ajmir	2 711	—	2 711	460 722	100
Kachh and Katiawar ...	10 158	52 613	62 771	7 594 775	38
Part of Indor and Sindiah...	—	7 000	7 000	710 000	0
Part of Bombay Pres. (undiv.)	—	unkn.	unkn.	unknown	100
	167 893	300 430	468 323	45 223 485	—
II. NORTH-EASTERN INDIA.					
North-West Provinces ...	81 748	5 125	86 873	33 465 803	97
Audh	24 213	—	24 213	11 387 741	100
Nipal	—	54 000	54 000	2 000 000	0
Most of Indor and Sindiah...	—	68 229	68 229	8 551 907	0
Bengal and Bahar	135 393	—	135 393	59 386 673	100
Bengal feudatory	—	36 634	36 634	2 845 405	0
Bhutan	—	unkn.	unkn.	unknown	0
Assam	46 341	—	46 341	4 908 276	100
Manipur	—	7 584	7 584	150 000	0
	287 695	171 572	459 267	122 695 805	—
III. SOUTHERN INDIA.					
Baroda	—	8 570	8 570	2 185 005	0
Central Provinces	84 208	29 112	113 320	11 548 511	86
Orissa	9 043	—	9 043	3 730 735	100
Bombay Presidency ...	65 950	—	65 950	11 183 860	100
Bombay feudatory	—	15 031	15 031	2 075 052	0
Barar...	17 711	—	17 711	2 672 673	100
Haidarabad	—	81 807	81 807	9 845 594	0
Madras	141 001	9 818	150 819	34 175 546	90
Maisur and Kurg	1 583	24 723	26 306	4 364 490	4
Kochi and Travankur ...	—	8 091	8 091	3 001 436	0
French and Portuguese ...	—	—	1 264	721 636	0
	319 496	177 152	497 912	85 504 539	—
Total for India... ...	775 084	649 154	1 425 502	253 423 829	—
BURMESE PENINSULA, &c.					
Chittagong	12 118	—	12 118	3 574 048	100
British Burma	87 220	—	87 220	3 736 771	100
Burmese Kingdom	—	192 000	192 000	3 500 000	0
Adjacent Islands	3 285	—	3 285	26 198	100
Ceylon	24 702	—	24 702	2 758 529	100
Straits Settlements	1 259	—	1 259	498 176	100
Perak, Selangor, Sangei Ujong	—	unknown	unknown	unknown	0
Thai (Siam)	—	309 000	309 000	5 700 000	0
Total	128 584	501 000	629 584	19 793 722	—

RIVER BASINS (*according to Maps of* 1882 *and* 1877.)

Divisions.	Basins.	Sub-divisions.	Area in square miles.	Chief Rocks.
I. NORTH-WESTERN INDIA, or Indian India ...	13	27	511 187	Alluvial and Tertiary in the plains; Metamorphic and Silurian in the hills.
II. NORTH-EASTERN INDIA, or Gangetic India ...	2	24	641 443	Alluvial, Vindhyan, and Gneissic; some Cretaceous.
III. SOUTHERN INDIA or Peninsular India	30	30	482 552	Metamorphic Gneiss, Cretaceous Trap, Laterite and Alluvial. Also Submetamorphic.
Total	45	81	1 635 182	
BURMESE PENINSULA ...	15	23	unknown	Metamorphic, Tertiary, and Cretaceous—in part

NOTE.—The watershed dividing Southern from Northern India, is the Vindhyan chain, and the southern edge of the Gangetic basin.
The watershed dividing North-Eastern from North-Western India is the western edge of the Gangetic basin, and the Aravalli range.
The watershed dividing the Burmese Peninsula from North-Eastern India is the southern edge of the Brahmaputra basin.

I.—NORTH-WESTERN INDIA.

Basins and Sub-Divisions.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfalls in feet.
1. *Indus Basin* (311 661).			
1. Indus proper, above Bunji	32 550	Metamorphic, Jurassic, Triassic, Silurian	No observations
2. The Yasin, Shigar, and Shiyok series, to Bunji	23 468	Metamorphic, Gneiss, Granite, Silurian, &c.	
3. The Indus proper, Bunji to Attak	9 499	Metamorphic, Silurian, Granite, and Carboniferous Jurassic	2·0 to 4·0
4. The Kashkar and Kabul basin to Attak ...	37 884	Metamorphic, Silurian, Lower Tertiary	1·0 and more
5. Western affluents from Attak to Leiah ...	30 777	(Unexplored); Tertiary in the plains; Silurian and Granite	0·5 and more

6. Eastern affluents from Attak to Leiah	11 743	Alluvial, Lower Tertiary, some Granite, Carboniferous and Jurassic	0·5 and more
7. The Jhelam	20 482	Lower Tertiary, Alluvial, Metamorphic, and Silurian ...	1·0 and more
8. The Chenab	26 725	Alluvial, Lower Tertiary, Carboniferous, and Metamorphic	0·5 and more
9. The Ravi	14 934	Alluvial and Lower Tertiary; some Metamorphic	0·5 and more
10. The Bias	7 122	As in the upper part of the Ravi basin	1·0 and more
11. The Satlaj and Panjnad...	41 085	Alluvial, Lower Tertiary, Metamorphic, and Carboniferous	0·5 and more
12. Western affluents from Leiah to Rohri ...	24 442	Alluvial; Upper and Lower Tertiary; partly unexplored ...	0·5 and more
13. Eastern bank from Leiah to Rohri	4 263	Alluvial only	
14. Western affluents from Rohri to Karachi ...	11 912	Lower Tertiary and Upper Tertiary, &c.	0·7 to 2·0
15. Eastern affluents and Delta, Rohri to Karachi	14 775	Alluvial; Upper Tertiary and Lower Tertiary	
2. *Nahwal, Guggar and Kantli, waste rivers* ..	29 923	Alluvial; some Upper and Lower Tertiary; Submetamorphic	1·5 and more
3. *Sambhar Salt Lake catchment*	4 628	Alluvial, Upper Tertiary and Submetamorphic	1·0
4. *Thar, or Indian Desert*	65 694	Alluvial; a little Jurassic and Submetamorphic	0·00
5. *The Raini, waste river*	2 984	Alluvial only	1·0
6. *The East Nara*	10 865	Alluvial; a little Upper and Lower Tertiary	1·0 to 2·0
7. *Kach Peninsula and both Ranns*	15 359	Alluvial; Upper Tertiary, Eocene, Trap, and Jurassic ...	2·0 to 4·0
8. *Katiwar Peninsula*	23 170	Alluvial; Eocene, Cretaceous, Trap...	2·0 to 4·0
9. *The Luni*	18 609	Alluvial; some Submetamorphic and Gneiss	No observations
10. *The Banas*	4 320	Alluvial; resembles the Luni basin generally	
11. *Saraswati and Jhinjuwara Rivers*	4 160	Alluvial; resembles the Banas basin generally	1·5 to 2·0
12. *Sabarmatti*	8 351	Alluvial; resembles the Mahi basin generally	1·5 to 2·0
13. *Mahi*	11 463	Alluvial, Gneiss, Submetamorphic, Trap, and Vindhyan ...	Noobservations

II.—NORTH-EASTERN INDIA.

Basins and Sub-Divisions.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfalls in feet.
1. *The Ganges Basin* (414 133).			
1 1*a*. Jamna proper, Hindan, and Sabi ...	27 752	Alluvial, Upper Tertiary, Silurian, and Metamorphic ...	1·5 to 6·0
1*b*. Banganga	7 924	Alluvial, Submetamorphic, and some Silurian	2·0 to 3·0
1*c*. Chambal and Sind rivers	68 090	Trap (Cretaceous), Silurian, Metamorphic, Submetamorphic, Alluvial	2·0 to 3·0
1*d*. Betwa, Ken, &c., above Allahabad ...	32 766	Alluvial, Metamorphic, Silurian, and Trap (Cretaceous) ...	2·0 to 3·0

II.—NORTH-EASTERN INDIA—(*continued*).

Basins and Sub-Divisions.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfall in feet.
The Ganges Basin—(continued).			
2. The Ganges proper, & Ramganga above Allahabad	34 800	Alluvial, Upper Tertiary, Silurian, and Metamorphic ...	2·0 to 7·0
3. Gumti, and north affluents above Ghazipur ...	11 524	Alluvial only	3·0 to 4·0
4. Gogra, and north affluents above Patna ...	72 183	Alluvial, Upper Tertiary, Silurian, Metamorphic, Jurassic, &c.	3·0 to 8·0
5. Tons, and south affluents above Shahabad ...	12 567	Silurian, and some Alluvium	2·0 to 4·0
6. Sohan, and south affluents above Patna ...	26 836	Silurian, Metamorphic, Jurassic, some Alluvium and Tertiary	3·0 to 5·0
7. Kosi, and north affluents above Sahib-ganj	32 260	In the plains, Alluvium; hills unexplored	3·0 to 10·0
8. Punpun, and south affluents above Sahib-ganj	14 006	Metamorphic, Alluvial, Gondwana trap, Lower Gondwana	3·5 to 5·0
9. Mahanad, and north affluents above Goalundo	11 052	Alluvial plains; in the hills Metamorphic and Silurian ...	4·0 to 11·0
10. Atrai, Karatoa, Jamuna, and Dhalesar tract, north of the Padda Ganges	11 698	Alluvium only	5·0 to 8·0
11. Western affluents of the Ganges and Bhagiratti, from Sahib-ganj to Calcutta	9 283	Alluvium, Metamorphic, Gondwana Trap, and Lower Gondwana; also coal measures	4·0 to 6·0
12. Damudah, Rupnarain, Haldi, and Kontai, or western affluents from Calcutta to Sagar I.	17 489	Alluvium and Metamorphic; also Silurian (transition) ...	4·0 to 6·0
13. The Delta below Jangipur, and west of the Megna	23 903	Alluvium only	5·0 to 6·0
2. *The Brahmaputra Basin* (227 330).			
1. 1*a*. Maghang Sanpu, above Gyala Sindong ...	94 800	No Geological Survey	No observations
1*b*. Unexplored intervening tract (approx.) ...	2 900	Ditto	"
1*c*. The Dihong branch, explored part	2 400	Ditto	"
2. The Brahmakand and eastern affluents ...	9 740	Ditto	"
3. The Kamla, Subansirt, &c., above Lakhimpur	16 280	Ditto	"
4. Dibru and southern affluents above Lakimpur	5 040	Ditto	7·5
5. Northern affluents Lakhimpur to Tezpur ...	2 800	Alluvial, Upper Tertiary, Metamorphic	6·5
6. Southern affluents Lakhimpur to Tezpur ...	8 240	Metamorphic, Alluvial, Cretaceous, Upper & Lower Tertiary	6·0 to 8·0

7. Northern affluents Tezpur to Gyabanda, including the Bhoroli and the Tista ...	33 060	Alluvial and Tertiary in the plains; hills not surveyed ...	6·0 to 50·0
8. Southern affluents Tezpur to Gyabanda ...	11 920	Metamorphic and Carboniferous	6·0 to 30·0
9. Barak and eastern affluents above Chandpur	34 280	Alluvial Upper and Lower Tertiary, Cretaceous and Carboniferous	6·5 to 50·0
10. Western drainage Gyabanda to Chandpur ...	2 020	Alluvial only	6·0
11. Eastern drainage into the Megna below Chandpur	3 850	Alluvial and Upper Tertiary	8·0

III.—SOUTHERN INDIA.

Basins.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfall in feet.
WESTERN DRAINAGE (106 586).			
1. *Dhaddar*	1 515	Alluvial only	2·0
2. *Narbada*	37 515	Trap; some Alluvial, Upper and Lower Gondwana ...	1·0 to 5·0
3. *Tapti*	25 243	Trap; some Alluvial	1·0 to 4·0
4. *Bombay Coast to Karwar*	19 110	Trap of cretaceous period; and Laterite	2·0 to 5·0
5. *Kalinadi and Gangawali Rivers*	3 315	Laterite and Metamorphic	2·0 to 5·0
6. *Kanarese Coast to Mangalur*	2 ,50	No Geological Survey	10 0 to 12·0
7. *Netravatti and Kassergod Rivers*	2 310	Ditto	10·0 to 12·0
8. *Muabbar Coast. Baikal to Calicut*	3 600	Ditto	10·0
9. *Ponassi River*	1 778	Ditto	No observation
10. *Kochi and Travankur Coast*	9 450	Ditto	2·0 to 10·0
EASTERN DRAINAGE (375 966).			
11. *Subanrikha and Buraballang*...	9 980	Alluvial, Carboniferous, and Metamorphic	3·5 to 6·0
12. *Baitarni*	5 652	Alluvial, Carboniferous, and Metamorphic	3·5 to 6·0

III.—SOUTHERN INDIA—*continued.*

Basins.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfall in feet.
EASTERN DRAINAGE (375 966)—*continued.*			
13. *Brahmani*	14 290	Alluvial, Carboniferous, and Metamorphic	3·5 to 6·0
14. *Mahanaddi*	50 730	Metamorphic, Lower Gondwana, and Vindhyan	4·0 to 6·0
15. *Ganjam Coast to Coconada*	19 000	Metamorphic ; some Alluvium	3·5 to 5·0
16. *Godavari*	118 900	Trap Laterite, Metamorphic, Lower and Upper Gondwana Alluvium	1·0 to 5·0
17. *Lake Koler*	2 578	Alluvium	3·0
18. *Kistna*	59 468	Metamorphic, Trap and Laterite Submetamorphic, Vindhyan, and Carboniferous	1·0 to 10·0
19. *Coast series ; three rivers*	6 817	Metamorphic, Submetamorphic	No observations
20. *Pennar*	21 992	Metamorphic, Submetamorphic, Vindhyan	5·0 to 6·0
21. *Lake Pulicut ; three coast rivers*	5 148	Alluvium and Tertiary ; and Metamorphic	4·0
22. *Palar*	8 054	Metamorphic, Upper Tertiary...	4·0
23. *Gingi River and Coast*...	1 150	Metamorphic and Cretaceous	No observations
24. *South Pennar or Poniar*	5 240	Metamorphic, Upper Tertiary, Cretaceous	"
25. *Vellar*	4 639	Metamorphic and Tertiary	"
26. *Kavari*	30 280	Metamorphic, Upper Tertiary, Cretaceous and Alluvium	1·0 to 10·0
27. *Valliar and two rivers*...	3 760	No Geological Survey...	No observations
28. *Vige*	3 478	No Geological Survey ; partly Metamorphic	"
29. *Vaipur and Coast*	2 122	Ditto ditto	"
30. *Chittaur and Coast*	2 688	Ditto ditto	2·0 to 5·0

NOTE.—The trap mentioned among the chief rocks is not intrusive, but contemporaneous with either the Cretaceous or Upper Gondwana beds.

IV.—BURMESE PENINSULA, &c.

Basins and Sub-Divisions.	Area in sq. miles.	Chief Rocks.	Some observed annual rainfall in feet.
WESTERN DRAINAGE.			
1. *Arakan Basins and Coast*	23 500	Partly Cretaceous and Tertiary; Gneiss in the hills ...	8·0 to 18·0
2. *Irawadi (incomplete,* 131 363*)*			—
1. Part above latitude 27°	unknown	No Geological Survey	No observations
2. From lat. 27° to Bamo	13 496	Ditto	,,
3. Western drainage Bamo to Mandalay ...	5 218	Ditto	,,
4. Eastern drainage, Bamo to Mandalay ...	15 475	Ditto	,,
5. Moo River and Kyendwen River to Kyendwen confluence	41 681	Ditto	,,
6. Eastern drainage from Mandalay to Kyendwen confluence	14 833	Upper Tertiary and Metamorphic	,,
7. Western drainage above Otphu	12 040	Lower Tertiary, &c.	4·0 to 6·0
8. Eastern drainage above Otphu	13 215	Upper Tertiary, &c.	
9. Delta and drainage below Otphu ...	15 405	Alluvial	5·0 to 18·0
3. *Sittoung*...	14 700	Upper Tertiary and Metamorphic	No observations
4. *Salwin* ... ... (approx.)	62 000	Partly Metamorphic	15·0 to 20·0
5. *Tenasserim Coast* ... ... (approx.)	14 000	No Geological Survey	5·0 to 20·0
6. *Mergui and Andaman I.*	unknown	Ditto	1·0 to 14·0
7. *Ceylon*	23 170	Metamorphic	4·0 to 10·0
8. *Malacca West Coast*	unknown	No Geological Survey	No observations
EASTERN DRAINAGE.			
9. *Malacca East Coast*	unknown	No Geological Survey	No observations
10. *Tenasserim East Coast*	,,	Ditto	,,
11. *Me Khlaung*	,,	Ditto	,,
12. *Me Nam*	,,	Ditto	,,
13. *Me Kong*	,,	Ditto	,,
14. *Anamese Coast*	,,	Ditto	,,
15. *Song Kai*	,,	Ditto	,,

RIVERS.

General Tables of Flood Discharge.

Flood Discharges of Indian Rivers, according to various reports.

River and Place.	Catchment Area.	Flood Discharge.	Discharge per sq. mile.	Coefficient (n) in the formula.
North-Western India.	Sq. miles.	C. ft. per sec.	C. ft. per sec.	*
Indus at Sakkar	250 000	380 000	15·2	0·3
Sohan (Punjab) at Lahor-road bridge	3 600	96 000	26·6	2·0
Markanda at Hassanpur, 1845	1 200	47 838	39·8	2·0
North-Eastern India.				
Jamna at Allahabad	118 000	1 333 000	11·3	2·0
Sai at Rai Bareli bridge ...	960	16 500	17·2	1·0
Sai at railway bridge	240	12 000	50·0	2·0
Gumti at Lakhnau bridge ...	2 000	22 366	11·2	0·8
Gumti at Saltanpur bridge ...	3 600	39 000	10·8	0 8
Loni at railway bridge ...	120	4 600	38·3	1·3
Kalliani at Lakhnau bridge ...	360	17 758	49·3	2·1
Sohan (Bengal) at causeway ...	34 000	1 700 000	50·0	7·0
Ganges at Rajmahal	286 000	1 350 000	4·7	1·1
Southern India.				
Combined Mahanaddi and Katjuri in flood of 1834 ...	67 000	1 850 000	27·6	4·6
Morna (Berar) at railway bridge	211	122 715	581·	20·0
Nalganga at railway bridge ...	213	153 846	722·	24·0
Godavari at Rajamandri ...	120 000	1 350 000	11·2	2·3
Kistna at Bezwara	110 000	1 188 000	10·8	1·9
Tumbaddra at Karnul ...	20 000	270 000	13·5	1·6
Kavari at Frazerpett	415	111 000	267·3	12·5
Kavari at Seringham	28 000	472 500	16·9	2·0
Penner at Nellur	20 000	359 100	18·1	2·0
Palar at Arkat...	3 700	270 000	74·2	5·7
Tambrapurni at Palamkatta ...	587	189 000	324·0	16·0
Chittar at Alligyapandrapuram	486	29 700	60·8	3·0
Vigay at Madura	1 600	43 200	27·0	2·0
Manjilanthi at Balagunta ...	90	10 800	121·5	4·0
Gadanamathi	29	28 088	972·0	23·0
Varhazanamathi at Periakolam	41	8 100	202·5	5·0
Irriti (Malabar)	336	149 850	446·0	19·0

* See tables in Hydraulic Manual.

Flood Discharges of Indian Rivers on the East Indian Railway, *by* S. Power, Esq., C.E.

Rivers.	Waterway. Catchment area.	Waterway. Breadth.	Waterway. Section below recorded flood level.	Recorded flood level	Estimated rainfall run off through.	Discharge per square foot of waterway to carry off estimated rainfall.	Mean velocity through in order to carry this off.	Estimated addition to waterway necessary to reduce this velocity below 2·5, existing waterway being = 1.	Rainfall of district.
	Square miles.	Lineal feet.	Square feet.		Inches per hour.	C. ft. p. sec.	Feet p. sec.		
Kurriamnassa	3 400	4 000	39 000	11	·25	162	15	6	Comparatively light.
Sohan	23 000	14 200	172 500	8	·125	11	10	4	
Punpun and Hallshar valleys	9 000	11 086	123 648	14	·25	162	11	4	
Kinal River	1 100	1 542	11 002	10	·25	162	16	6	
Hill streams west of Jamalpur	240	1 670	7 385	80	·5	323	10	4	
Do. Jamalpur to Sahibganj	2 650	6 796	59 486	23	·5	323	14	5	Heavier than that west of Manghir.
Do. Sahibganj to Tinpahar	52	1 641	7 952	155	·5	323	2	1	
Do. Tinpahar to Baluva...	66	1 176	2 476	144	·5	323	2	1	
Gumani River	520	1 639	10 165	20	·5	323	16	6	
Hill streams between Gumani and Mullarpur	1 200	5 824	53 301	44	·5	323	7	3	
Adjai and Mor valleys ...	3 640	7 752	120 300	30	5	323	10	4	
Khanu to Haurah	—	14 000	65 000	—	—	—	—	—	

DETAILS OF THE BREADTHS, &c, OF VARIOUS LARGE RIVERS AT THEIR ENTRANCES (*from* HEYWOOD).

Details.	Ganges.	Kistna.	Godavari.	Kavari.	Mahanaddi.
Extreme breadth	$5\frac{1}{4}$ miles	$1\frac{1}{2}$ miles	4 miles	1 mile	3 miles
Extreme breadth of channel	$2\frac{1}{4}$,,	$1\frac{1}{4}$,,	$2\frac{1}{2}$,,	$\frac{3}{4}$,,	—
Least breadth of channel	$1\frac{1}{4}$,,	$\frac{3}{4}$,,	$1\frac{1}{2}$,,	$\frac{1}{2}$,,	$\frac{1}{2}$ mile
Fall per mile, in feet	— feet	1·17 feet	1·09 feet	3·5 feet	1·67 feet
Rise in mansun, in feet	27 ,,	35 ,,	30 ,,	12 ,,	32 ,,
Greatest depth in dry season	30 ,,	10 ,,	10 ,,	6 ,,	—
Surface current in floods, in miles per hour	4 to 7 miles	$7\frac{1}{2}$ miles	$4\frac{1}{4}$ miles	6 miles	—
Flood section, in square feet	288 000	153 000	216 000	37 800	—
Flood discharge, in cubic feet per second	1 800 000	1 500 000	1 500 000	300 000	1 800 000
Least discharge in dry season ,, ,, ,,	45 000	1 125	2 250	None	—
Longest duration of flood	40 days	10 days	10 days	10 days	12 hours
Area of delta, in square miles	—	—	3 000	—	5 000

LATERAL CURVES OF RIVERS OF FIXED REGIMEN. (FERGUSSON.)

Reaches of River.	Direct distance.	Distance by river.	Width of stream, at low water, in dry season.	Oscillations.	Length of oscillation.
	Miles.	Miles.	Feet.	Number.	Miles.
GANGES.					
Allahabad to Chunar	62	104	[illegible]	17	3·7
Chunar to Baxar	80	113	[illegible]	20	4
Baxar to Patna	74	96	[illegible]	15	5
Patna to Manghir	82	106	[illegible]	$11\frac{1}{2}$	7
Manghir to Rajmahal	96	108	[illegible]	10	9·5
Rajmahal to Rajapur	90	100	7 000	10	9
Rajapur to Patna	30	44	4 000	6	5
Patna to Jafirganj	32	36	3 000	8	4
BHAGARATTI.					
Choka to Naddia	96	120	1 200	62	1·5
Naddia to Chogdah	24	30	2 000	9	2·5
Chogdah to Calcutta	34	42	3 000	11	3
JELLINGHI.					
Jellinghi to Naddia	50	112	1 000	42	1·2
MATA BAGH.					
Ganges to Kumar	18	28	1 500	9	2·0
Kumar to Kissanganj	30	50	800	46	0·66
Kissanganj to Chogdah... ...	24	29	500	47	0·5

Brief Accounts of Indian Rivers.

North-Western India.

The Indus Delta.—The first useful survey of this delta was made by Lieut. Carless, I.N., in 1837.

The Delta commences below Tatta, at about 50 miles from the sea. The Setta, or Eastern arm, is the main channel, discharging fresh water in the dry season; it throws off the Titiah at 35 miles from the sea; and nearer the sea divides itself into the Hajamri, the Kediwari, and the Wanyani channels, mouths, or creeks, all of which give a small dry season discharge, the Kukiwari being the grand discharging mouth. The wet weather channels, carrying off inundation water to the sea, are—1, the Fuleli, branching off from the Indus above Haidarabad, and discharging at the Kori mouth; 2, the Pinyari, branching about half-way between Haidarabad and Tatta, and discharging at the Seer mouth; 3, the Baggaur, from the Delta head, and forming a large western channel, from which the Phitti, Pintiani, Juah, and Richel mouths branch; 4, the wet weather channels, branching from the Setta, named the Kukiwari, Kaher, and Mal.

But the changes of course of the deltaic channels are frequent, very rapid, and sudden: practised pilots are liable to error from the want of visible objects on this dreary waste. The tides are irregular, the tidal rise is only four feet in some places, and ten feet in others, and the shore current setting E.S.E., is feeble. The coast navigation is carried on from October to March; soundings are trusted everywhere as the coast shelves gradually. In February there are occasional gales from the west and a heavy sea; but the Indus is considered closed for the season by the middle of March.

The Hajamri mouth has a navigable channel 1 800 feet wide; the Kediwari entrance is a little wider: the Kukiwari has a much-divided, intricate mouth, a mile wide, the principal channel being 1 500 feet wide. The average width of the Setta, up to the Titiah, is about 2 100 feet, its current $2\frac{1}{4}$ miles per hour as an average, in a few places $3\frac{1}{2}$. Between the Titiah and Tatta there are shallows and intricate navigation; the average current is $3\frac{1}{2}$ miles per hour, in some places 5. At Tatta, the banks are $1\frac{1}{4}$ miles apart, the waterway occupying only a third of this space; above it intricate navigation recommences, and a con-

tinuous channel up to Haidarabad gives only 5 or 6 feet of water, the greatest depth in this section being 8½ feet.

As to the periodical rise of the Indus, as first observed by Lieut. Wood, at Haidarabad it is 15 feet; just below Tatta the swell overtops the banks; at the confluence of the Hajamri, 22 miles from the sea, the rise is 13 feet; and as the banks are 11 feet high the land is inundated. At Vikkur the rise is only 6 feet above high-water mark of the ocean tides; and on the coast-flats it is only 2 feet. During the swell the high tide causes a heavy bore at most of the mouths, but it soon loses force, as it ascends for only seven miles. In the Delta the inundation water is retained by dykes 6 feet high along the banks, and small banks are thrown up round villages. The silt, determined at from 3 to 4 cubic inches in a cubic foot of inundation water, contains fine clay, carbonate of lime, micaceous sand, common salt, carbonate of soda, and nitre. The soluble constituents in the water are common salt, carbonate of soda, and nitrate of potash. The water is not very pleasant for drinking, and the natives consider it unwholesome. There are exceptional floods of great force at long intervals, which alter the channels very much; also serious earthquakes and upheavals that have affected the Kori mouth very greatly.

The Indus Valley.—Lieut. John Wood, I.N., first surveyed the Sind or Indus River throughout up to Attock in 1838.

The following table gives the number of days occupied in transit by country boat on the navigable stages of the river, upwards as far as Kalabagh, downwards from Attak: this latter place is 942 miles from the sea by river, or 648 miles in a straight line.

Stages.	Upwards.		Downwards.	
	Dry season.	Freshes.	Dry season.	Freshes.
Seaport to Haidarabad ...	15	7	2½	2
Haidarabad to Sehwan ...	8	4	3	2
Sehwan to Kori	14	7	7	4
Kori to Mittan	14	6½	6	3½
Mittan to Dera Ghazi Khan ...	10	4	4	2
D. Ghazi to D. Ismail Khan...	19	10	10	3½
D. Ismail Khan to Kalabagh	12	7	7	2
Kalabagh to Attak	15	(impract.)	1½	1
	107	45½	41	20

The river above Attak, the confluence of the Kabul river, up to its sources near Gangri or Kailas Parbat in Thibet, is little known.

Steamers were employed on the Lower Indus at an early date, about 1835; steamers, drawing flats, arrived as high as Dera Ismail Khan in 1862.

The freshes commence in March; sometimes at the end of April. High flood is most frequent in August, and the lower stage commences at the end of October. The current in the dry season varies from $2\frac{1}{4}$ to $3\frac{3}{4}$ miles an hour; in the freshes from $5\frac{1}{4}$ to 7, arriving sometimes at a maximum of $8\frac{1}{8}$ miles an hour; in the Kalabagh gorges it exceeds 10 in freshes. The ground currents are very little less than the surface currents.

The fall per mile from Attak to Kalabagh is 1·7 feet; from Kalabagh to Mittan 0·7 feet, and from Mittan to the sea 0·5 feet. The width of the water surface in the dry season averages 2 000 feet, or varies from 1 500 to 5 000 feet. The greatest soundings in dry seasons vary from 9 to 15 feet, in freshes 24 feet; but an exceptional sounding in the Kalabagh gorge gave 186 feet. The lowest ordinary soundings as fair averages for a continuous course are thus:—

	Feet.
In the Delta, in December and January	6
Up to Sehwan, in January and February	6 and $4\frac{1}{2}$
Up to Bakkar, in February and March	$4\frac{1}{2}$
Up to Mittan, in April	3
Up to Kalabagh, in May, June and July	3

But there are numerous shallows in some parts precluding at some seasons a draught of more than 2 feet, even with the aid of experienced pilots.

The maximum rate of discharge is estimated at 446 080 cubic feet per second in August, and at 40 857 in December; the total annual discharge at 5 383 600 934 400 cubic feet.

Some of the values thus given by Lieut. Wood are quoted from the Memoir of the expedition of Captain A. Burnes, and were observed by Captain Sir Keith Jackson and others at a time when such observations were of a rough, incomplete nature.

The later information about discharges is as given following. The source of the Indus having been determined approximately by the explorations of Pandit Nain Singh, its total length is about 1 800 miles.

At Attak, certain recorded velocities were as follows:—

In hot seasons, opposite the fort, velocity 13 miles an hour; at tunnel site, in cold season, 5 to 7 miles an hour—in hot season,

13 to 14 miles an hour; surface velocity at centre, Dec., 1869, 9 miles an hour.

The rise of ordinary floods is from 5 to 7 feet in 24 hours only, and is 50 feet above cold weather level. The flood of 1841 was 92 feet above cold weather level, and that of 1858, 80 feet.

The fall of the Indus near Bakkar is 0·75 feet per mile.

Discharges—At Kalabagh.

	Cubic feet per second.		Cubic feet per second.
In December, 1871 ...	21 220	January, 1873 ...	20 781
January, 1872 ...	18 657	January, 1873 ...	20 541
December, 1872 ...	21 878		

At Dera Ghazi Khan.

January, 1873 ... 18 657

Average gauge readings monthly—At Dera-Ghazi-Khan.

April, 1872 ...	6·27	August, 1872 ...	7·97	Dec. 1872 ...	3·46
May, 1872 ...	7·32	Sept. 1872 ...	6·19	Jan. 1873 ...	3·55
June, 1872 ...	9·28	October, 1872 ...	4·83	Feb. 1873 ...	3·23
July, 1872 ...	9·81	November, 1872	3·98	March, 1873	3·58

The River Kuram.

In Jan., 1873 ... 545 Cub. ft. p. sec. (included with the Indus discharges).

Barra River, at the Lahor and Peshawar-road bridge, 7 miles west of Peshawar, the waterway allowed is 180 lineal feet. In the flood of July, 1861, the flood rose 18 feet in 5 minutes, and had a surface velocity of 15½ feet per second. The soil of the bed consists, first, of 18 feet of silt and loose sand, then 8 feet of firm sand resting on clay.

Sohan River, Punjab, at Lahor and Peshawar-road, east of the Indus, has a catchment area of 573 square miles; maximum flood depth, 15 feet; mean velocity, 8 to 9 feet per second; slope of bed, 14 feet per mile; calculated mean velocity, 13 feet per second; flood discharge, calculated from sections 91 000 cubic feet per second = ¼ inch over the catchment basin; the perennial stream is never less than 1 foot deep. Bed at surface, boulders—at 11 feet conglomerate blocks; at 16 feet, a hard, dry foundation; width of river at site 1 000 feet, but a little above only 750; clear waterway of bridge, 945 lineal feet. A second Sohan, above it, is also called the Tutar or Tutalnás.

The Jhelam.—Mr. Forster reported on the navigable condition of this river in February, 1861. He states that after passing the

town of Jhelam, it flows S. 60° W. for 50 miles to Pind Dadun Khan and 45 more to Kushab; afterwards in a course S. 9° W. for 70 miles to its junction with the Chenab, near Trimmo Ferry; but the whole distance is increased by windings to 200 miles. The breadth of the stream is generally 750 to 900 feet, but varies from 120 to 2 100: the navigable channel from 75 to 240 feet wide, but sometimes extends from bank to bank. The general depth is 5 to 7 feet, at extremes 1·5 foot and 22 feet. The current averages $1\frac{1}{2}$ miles an hour, seldom exceeds 2, but after rain may be 4 miles an hour for a day or two. The banks are 8 to 10 feet high; below Kushab they are 20 to 25 feet. There are few snags above Kushab, but more below it. There are no rocks or stones except near Jalalpur at the foot of the Salt range and at Jhelam. The shallows, shoals, and intricacies are the obstructions to navigating vessels of more than 1·5 foot draught during the low water season. A pilot for every 25 miles is necessary.

The unfavourable parts of the course are, at 4 miles below Jhelam, for mile; and from Malikpur to Jalalpur for 4 miles.

At five miles below Jalalpur, at Pind Dadun Khan, and at Bhera, there are shoals, shallows, and difficulties from the tortuous course between Bhera and Kushab.

From Kushab to Trimmo, a depth of 2 feet can be generally depended on; but in this part there are two bad places, at Bakki and Shahkikot.

The Chenab.—Mr. Forster reported on the navigability of the river in 1861. From Trimmo Ferry to Multan 80 miles, the river is navigable all the year to a draught of 2·5 feet. The current averages $2\frac{1}{2}$ miles an hour, but sometimes more. The worst part is at Rangpur, about 12 miles above Multan.

The Ravi, the Satlaj, and the Bias.—The following are recorded discharges of these rivers:—

The River Satlaj.

Date.	Place.	Discharges in c. ft. p. sec.
21 Jan. 1856	Proposed site for headworks of Canal	2 781
12 Feb. 1857	Proposed site for headworks of Canal	4 135
26 Jan. 1859	„ „	4 027
20 Dec. 1859	„ „	4 663
21 Jan. 1861	„ „	4 461

N.B.—Perhaps these are in excess.

The River Bias.

Date.	Place.	Discharges in c. ft. p. sec.
19 April, 1872	At Naushehra	7 498
19 Oct. 1872	„ „	8 797
19 Dec. 1872	„ „	4 901
19 Jan. 1873	„ „	5 117
19 Mar. 1872	At Pakhowal	3 464

The River Ravi.

Date.	Place.	Discharges in c. ft. p. sec.	Date.	Place.	Discharges in c.ft.p.sec.
19 Dec. 1872	Shahdera, Lahor, 94 miles.	703	19 Jan. 1873	Bhátiah ...	271
			19 April 1872	Sidhuri ...	7 689
19 Dec. 1872	Alpah, below escape 147 miles.	879	21 Sept. 1872	"	13 452
			19 Dec. 1872	,, ...	1 866
19 Dec. 1872	Bhátiah	509	20 Jan. 1873	,, ...	2 296
19 Jan. 1873	Shahdera	687	19 Mar. 1873	"	3 579
19 Jan. 1873	Alpah	478			

River Markanda (*affluent of the Ghaggar*).—Observations by C. J. Campbell, Esq., C.E., at Hassanpur, in 1859.

The bridge site, where the banks are well defined, is about three miles below Hassanpur.

Width of channel	1 577 feet.
Sectional area	6 938 square feet.
Hydraulic slope	2·72 feet per mile.
Mean velocity	5·15 feet per second.
Discharge	35 370 cubic feet per second.
Flood of 1845	47 838 cubic feet per second.
Flood depth	10 feet.
Ordinary flood depth	6 to 9 feet.
Waterway of bridge	1 073 lineal feet.
Height of roadway	24 feet above bed.
The soil of the bed is	Sand and silt for 40 feet in depth.

North-Eastern India.

The Jamna.—The course between Delhi and Agra, about 30·0 miles, was surveyed by Mr. E. Battie, in October, 1855, to July, 1856. He states that there are shoals at every mile. For boats drawing more than 2 feet of water it is not navigable, as the passages are intricate and change constantly. There are sand shoals, kankar shoals, and block kankar.

At the Sirsawa bridge of the Delhi Railway, 37 miles S.E. of Amballa, the waterway allowed is 2 376 lineal feet. At this place the Jamna is constant for six months, from April to September, being snow-fed: it rises in March, and falls in October. At the site the soil is gravel and coarse sharp sand; above the bridge site it consists of large 14 lb. boulders. Its flood velocity is 8 miles an hour, scouring the bed, carrying along the boulders and depositing them 30 feet below the ordinary bed of the river. In 1867, the river rose in flood to 2 feet above its banks; in 1868, to 3·17 feet.

The floods of the Jamna at Allahabad were recorded by Mr. Sibley, C.E., from 1861 to 1865, observations being taken daily at 6 A.M. and 6 P.M. The extreme variation of ordinary level within the five years' observations was 2 feet; the extreme

variation of lowest level was generally also 2 feet. The lowest water occurred between the 19th and 28th April, when the rise from snow melting begins. The great rise due to the periodic rains generally begins on the 19th or 20th June. The highest flood generally occurred between 22nd and 26th of August; the highest flood recorded was in 1832, a little higher than that of 1861.

Flood-gaugings of the Jamna.

		Feet.	
In 1861 R. L.	high flood	161·6,	8 days over 155, and 4 days over 160.
1862 R. L.	...	144·5	lowest recorded flood.
1863 R. L.	...	155·	
1864 R. L.	...	152·5	

The floods of 1861 were exceptionally long in duration. The lowest recorded flood was 30 feet above low water level, the average 40, and the maximum 50 feet; the maximum velocity was 12 feet per second, and for 12 days remained more than 10 feet per second. At the period of greatest discharge the mean surface velocity was 10 feet per second, and the mean sectional velocity 9 feet per second; the sectional area at that level being 145000 square feet, the discharge per second was 1⅓ million cubic feet.

The fall of the Jamna at Agra is 1·25 feet per mile.

This river supplies the Eastern Jamna canal with about 1 065 cubic feet per second, the Western Jamna canal with about 2 500, and the Agra canal with 800 cubic feet per second.

Discharges of the River Jamna.

Date.	Place.	Cubic feet per second.
6 June 1872	Mandawala	1 388
6 June 1872	Bud	5 126
29 July 1872	Chaogaon	144 890
19 Dec. 1872	Railway bridge	2 128
19 Dec. 1872	West Ghat	2 037
19 Jan. 1873	Railway bridge	2 554
20 Jan. 1873	West Ghat	2 934

The *Sohan River*, in Bahár, is 425 miles long, rising near Ammar Kantak in Central India, the first 325 miles of its course are in rocky country; it emerges from the Kaimor hills at Rhotas, 100 miles from its confluence with the Ganges at Patna; the last 100 miles being in the plains. The river is three miles broad at Telothu; and generally in the plains is two miles in breadth; for eight months in the year the stream is a quarter of a mile broad. The extreme flood discharge is said to represent

$2\frac{3}{4}$ inches of rainfall over the whole catchment area in 24 hours (the heavy floods never exceeding four days); in this state half the water is thrown over the country below Massaura. The lowest discharge in dry seasons is 4 000 cubic feet per second. During the rainless year referred to in the table of discharges, the rain from June to October inclusive was at Shahabad, 21·3 inches; at Bahar, 18·9; and at Patna, 19·6: it is generally 35 inches at each place; though in the year following that rainless year the fall at Patna was 50 inches.

At Dehri, a town 65 miles above Patna, are the headworks of the Sohan canals, and the causeway of the Grand Trunk road. The channel of the river here varies from 2 to $2\frac{1}{2}$ miles in breadth, and has a fall of from 1·75 to 3 feet per mile, and its flood rise, or difference between summer and high-flood level, is from 14 to 20 feet; its discharge varies from 4 000 to one million cubic feet per second. The bed is composed of shingly sand to a great depth.

It is unfortunate that the diagrams of discharge of this river, as well as those of the Ganges, the Kodra, the Kura, Punpun, Durganti, Chandarprobah, Kuramnassa, Morhar, and Sura, prepared by the engineers of the Sohan canals in 1872 and 1873, are not yet available in England.

Discharges of the River Sohan, Bengal.

Date.	Place.	Cubic feet per second.
8 Jan. 1855	At causeway and headworks of canal.	5 750
1 Feb. 1855	,,	4 624
1 Mar. 1855	,,	11 020
Ordinary minimum	,,	4 000
Extreme drought	,,	960

The Gogra.—This river was surveyed in March to May, 1852, by Gaskoin, from Faizabad in Oudh to its junction with the Ganges at Chaprah. The average depth of water was 8 or 9 feet; but in many places 20 feet, in some 30 feet; nowhere less than 4 feet. The impediments to navigation consisted of tortuous parts, snags, kankar islands, and hard sand ridges (masina) at right angles to the current. There is also much quicksand. The river is very straight, and the current is strong. The channel is generally broad, but in three short reaches it is only 70 feet wide. The navigation is reported good up to Bairam Ghat, 30 miles above Faizabad.

The Ganges.—Length 1 514 miles. The older discharges of this river, given in the tables of Beardmore's work, were taken under the following conditions:—

1st. The quantities at Banares were taken from a section by Prinsep, on the 25th April, 1829, after a long interval without rain: the area of the section was 48 650 square feet, the width 1 400, the mean depth 34·75 feet, the mean velocity 0·39 feet per second; the maximum discharge at the same place was computed when the river was 3 000 feet wide, and had an average depth of 58 feet, and sectional area 175 000 square feet, the mean velocity being about 7·33 feet per second.

2nd. The gauging at Kot, near Balliah, was taken by Lieutenant Garforth, in the first week of May, 1850, when the river was at its lowest; the sectional area was 5 876 square feet, width at water level 1 125 feet, mean velocity 2·35 feet per second; the maximum velocity in mid-channel was 3·30 feet per second, which greatly exceeded that in other places where the river was deeper; the maximum depth in this section was 9·42 feet in a narrow place only 120 feet wide, the remainder of the section varying from 4 to 6 feet in depth.

3rd. The gauging at Sikrigali was taken on the 9th March, 1829. At this place, 30 miles above the Delta, the Ganges has received the Gogra, the Gandak, Kusi, Sohan, and other rivers, whose united volume is frequently more than that of the Ganges proper, Jamna, and other affluents which form the river at Banares. The data for gauging were as follows: breadth about 5 000 feet, depth 3 to 5 feet, sectional area 15 000 square feet, mean velocity about 1·43 feet per second; in extreme freshes the breadth is about 10 000 feet, mean depth 28 feet, sectional area 280 000 square feet, the mean velocity being about 7·33, and the maximum 10·00 feet per second.

The three sets of deduced discharges were thus:—

	Catchment.	Mean Discharge.	Max.&Min. Discharge.	Mean Discharge per Sq. Mile.	Max.&.Min. Discharge per Square Mile.	Depth run off.
Ganges	Sq. miles.	C. ft. p. s.	C. ft. per sec.	C. ft. p. s.	C. ft. p. s.	Feet.
At Banares ...	180 000	250 000	1 285 000	1·38	7·15	1·57
At Kot ...	192 000	—	(min.) 13 800	—	(min.) ·071	—
At Sikrigali...	330 000	500 000	1 800 000	1.51	5·45	1·71

The Ganges seems to have preserved its general course for ages down to Suti, 34 miles below Rajmahal, where, at some period within the range of tradition, some alteration in the banks

caused it to be diverted from its former western course, now known as the Bhagiratti as far as Naddia, and below it as the Hughli (not an indigenous name) to its present eastern course by Rampur-Bauliah and Jellinghi, which joins that of the Brahmaputra to form the Megna estuary.

The fall of the Ganges at Sukertal is 1·5 feet per mile; from Gurmaktesar to 60 miles south of it it is 1·25 feet per mile, and from Khanpur to Allahabad it is 0·75 foot per mile. The fall of the Bhagiratti, between Rajmahal and Mirzapur, in 190 miles is 0·281 foot per mile. Details of the curves of the Ganges are given in Fergusson's table on page 251.

There is a lamentable want of available accurate modern information as to the physical conditions and discharges of the lower part of the main river.

The Hughli is formed by three offshoots from the Ganges, the Bhagiratti, the Jellinghi, and the Matabangah; and by many independent rivers that fall into the Bhagiratti, named the Banslo, Brahmiri, More, Ajai, and some smaller; at 40 miles below Calcutta the Damuda joins it; at 48 the Rupnarain; at 72 the Haldi; at 92 the Rasalpur, near to the mouth. There is only one offshoot, Channel Creek, branching at 30 miles from the sea. Tidal influence extends in the dry season to Naddia, 170 miles from the sea, or 70 above Calcutta. The Ganges has an average flood discharge of 1 355 000 cubic feet per second, maintaining a high-water level from the middle of June to the middle of October. In its dry weather state it discharges 80 000 cubic feet per second, the water being then 26 feet below the banks, or 20 feet below high flood. The beds of the offshoots from the Ganges are generally above the low-water level of the Ganges itself, hence they do not receive any water from it in dry weather. The aggregate discharge by the three offshoots is thus in cubic feet per second: in June, 50 000; in July, 150 000; in August, 200 000; in September, 150 000; in October, 100 000; in November, 20 000.

As to the tributaries, their supply from October to May is very small, even nothing; but during the rainy season their average united supply is 70 000 cubic feet per second. Their high floods occur about once a month in the rainy season, and last three or four days; in such a state their aggregate supply to the Hughli is about 700 000 cubic feet per second. The tributaries below

Calcutta supply during high flood—Damuda, 100 000; Rupnarain, 600 000; Haldi, 100 000 cubic feet per second. And their floods are like those of the upper tributaries. Their ordinary rainy season supply is about a quarter of that in high flood; their dry season supply is trivially small.

There is also a dry weather supply of fresh, clean water oozing from the porous banks of all the channels. This was measured at 20 000 cubic feet per second at a point 30 miles above Calcutta and is the dry weather supply of the Hughli. Its rainy season supply from June to September varies from 300 000 to 500 000 cubic feet per second at Calcutta to 40 miles below it, where it is, perhaps, doubled. The average velocity is 4 miles an hour, the highest 7 miles an hour. The amount of silt in floods at Calcutta is $\frac{1}{1728}$ of the water, or about 108 000 000 cubic feet yearly. At Saugor Island this annual total is nearly doubled.

The following table shows the tidal height during the height of the rains, and during high tides of the dry season, which are unaffected by rain:—

Average tidal levels, in feet above zero of gauge.

	July to October. Wet Season.				November to June. Dry Season.			
	Spring.		Neap.		Spring.		Neap.	
	H. W.	L. W.	H. W.	L. W.	H. W.	L. W	H. W.	L. W.
Saugor Island ...	18·	1·5	11·5	6·5	17·5	1·	11·	6·
Mud Point	20·5	2·5	14·	7·	19·	1·	12·	6·
Diamond Harbour	20·	3·	14·25	7·25	18·	1·	11·5	5·
Fultah	20·	4·	14·25	7·5	17·5	1·25	11·	5·
Calcutta	20·5	5·	14·5	8·	17·	1·5	10·	4·5

The capacities of the rivers as tidal reservoirs in holding spring tides are thus estimated:—

	Cubic feet.
The Damuda for 30 miles of length	1 647 millions.
The Rupnarain for 50 miles ,, ...	5 051 ,,
The Hughli above Calcutta	5 943 ,,

As to current: during the rainy season the flood-tide affects it very little, sometimes not enough to swing moored ships, although the tidal level may be nearly at full. During the dry season the fresh water supply hardly affects the tidal action, which gives a full tidal volume of about 400 000 cubic feet per second at Calcutta; the flood lasting five hours, the ebb seven

hours. Dividing the dry season into two parts; while the N.E. wind blows from November to February, the spring tides run 3 to $3\frac{1}{2}$ knots per hour, the neaps $1\frac{1}{2}$ to 2; while the S.E. wind blows from March to July, the spring tides run 4 to 6 knots an hour.

As to the navigation below Calcutta: the estuary from the sea up to Saugor Island is in a condition about corresponding to that in 1836. Between Saugor Island and Mud Point the courses have altered, and are continually changing. The river has become very much worse from Mud Point to Kalpi, but from Kalpi to Calcutta it is very little changed. Some attempts were made to scrape and harrow away some shoals in 1863. In 1864 Mr. Leonard, C.E., proposed some works for improving the channel. Mr. Obbard, River Surveyor, compiled the history of the various channels and shoals from 1745, and supported the proposal to divert the Damuda into the Rupnarain. Apart from the above information, compiled from Mr. Leonard's report, there is no doubt that the river is seriously deteriorating, and that the tidal action and principles are very imperfectly understood by the officials dealing with the matter.

The Damuda.—This tributary rises in the Sonthal Hills, the upper portion of its basin being comparatively unknown; it becomes a single and defined channel at about 23 miles above Raniganj, and passing through the coalfields of that tract, enters the yellow clay of the delta near Burdwan, 52 miles below Raniganj, whence it continues to Selimabad. At Selimabad, 16 miles below Burdwan, is an old branch of the Damuda, which flows into the Hughli above the town of that name; but the present course is by Ompta to the Hughli, opposite Fulta, a length of 60 miles. This river is interesting on account of its floods frequently inundating the country; remedial measures, the improvement of its embankments and the damming up of the old branch, were unsuccessfully attempted in 1857 by various military engineers. There is a large amount of Governmental correspondence on this subject, but no valuable hydraulic data; in fact, the velocity tables of the floods give as a maximum 77 feet per second, or 5 miles an hour, or less than a half what it must be. In 1872–73 some hydraulic observations were made by the civil engineers employed on the Orissa canals, but the records are not yet available.

The Damuda, with a catchment basin of 7 000 square miles, has a flood discharge representing 0·125 inch per hour of rainfall.

The Brahmaputra.—Major Rennell traced this river in 1765 to 400 miles above its conflux with the Ganges, in lat. 26°, long. 91°; finding it larger than the Ganges, and approaching within 120 miles of the Sanpu river. Chevalier found it navigable for 600 miles.

During the course of 400 miles, from its entry into the plains in E. long. 96° to Goalpara, where it turns southward, the Brahmaputra has three large branches, the Bramakund, the united Dihong-Dibong, and the Subansiri. The Bramakund, explored by Griffith in October, 1836, was 150 feet wide, the bed was 300 feet wide, and the flood-rise, by marks, was 8 feet. The exploration of Captain Bedford's party in 1825–26 showed that the Dibong was also a small stream knee deep, and only 90 feet wide, on 14th December, 1825. The Dihong, in lat. 28° 5′, was 600 feet wide, calm, with a slow current; but in flood probably 900 or 1 200 feet wide, and of immense depth; the discharge at this place was about equal to that at its confluence, 50 000 cubic feet per second, according to Wilcox. The Dihong is reported to be formed of two large branches, one from the East, the other from the West. Wilcox examined the Subansiri (or Kamla), on the 28th November, 1825 or 1826; at its confluence its discharge was 16 000 cubic feet per second; he compared it to the Ganges at Allahabad in December.

In 1869, Cooper ascended the Dihong for a few miles in the plains, when at high flood (in September or October?), it had a deep, swift current, and was a quarter of a mile wide at its narrowest part.

Abbé Desgodins believed that the fall at Bramakund is that of the Maghang Sanpu (also called the Nari Chu Sanpu), into the Brahmaputra ("Annals of the Thibetan Missions," March, 1877).

It must be noticed that there are several Sanpu rivers in Thibet, and that the word may be a generic term, as it is applied to the Chachu, the Charta, and the Raka, tributary affluents of the Maghang. The Sikung Sanpu is the Kamlapani, a stream independent of all the former. There are probably also several other Sanpu valleys to the north-east of the Sikung.

In 1878, Harman surveyed 1 500 square miles of country

on these upper tributaries, and measured the following discharges:—

		Width. Feet.	Area. Square feet.	Discharge Cubic feet per sec.
Subansiri at Pathalipaan ...	25–28 Feb. at low water	1 077	9 637	16 945
United Dihong and Dibong, 1 mile below confluence	24–27 March, at a rise of 3 ft.	2 295	25 105	110 011
Dibong alone, at 1 mile above the confluence ...	27 March, at a rise of 5 ft.	948	10 992	47 383
Brahmaputra, 9 miles above Sudiya ...	2–6 Apr. at a rise of 3 ft.	2 981	16 396	66 251
Brahmaputra at 3 miles above Dibrugurh ...	4–18 March, at low water.	1 905	24 477	116 115

The Dihong has lately been traced to 94° 52′ 8″ long.; 28° 30 lat.; elevation 7 000 feet. An explorer, N-m-g, under the instructions of Harman, followed the Maghang Sanpu river down to Gyala Sindong, about 94° 12′ 8″ long. and 29° 43′ lat.; elevation 8 000 feet.

On November 30th, 1874, Nain Singh had followed the Maghang Sanpu to Chitang; he described it as very sluggish, in a bed 1 500 feet wide, and 20 feet deep at the utmost; its valley being several miles wide. Its discharge was hence about 30 000 cubic feet per second.

Probably some river from one of the neighbouring Sanpu valleys supplies the Dihong branch of the Brahmaputra, but the communicating stream is not determined with certainty.

At Goalpara the Brahmaputra is 4 500 feet wide, and of rapid current. Its depth is variable. Its lower tributaries are the Suma, Barak Gumti, the Tista, and the Megna river. Its banks are marsh and jungle, subject to inundation from March to September on large reaches. Its course is tortuous. After joining the Ganges, the estuary formed is 20 miles wide, termed the Megna estuary. Its down tide runs at 10 miles an hour in some places.

IMAGE EVALUATION
TEST TARGET (MT-3)

6"

SOUTHERN INDIA.

The Subanrikah.—The survey of this river was effected by Messrs. Fennesy and Brine before May, 1861, when large protective dykes were commenced. The neaps, sections, and descriptive accounts apparently have not been reproduced and printed, or do not accompany the official correspondence about the Hijalli dykes.

The Mahanaddi, length 490 miles, and its Tributaries.—The following are reduced levels of the flood and low water sections of the Mahanaddi for last 200 miles.

At	Miles.	Flood. Feet.	Low-water. Feet.
Sonpur	0	365·5	335·5
Barmul Pass entrance	60	245·5	175·5
Do. exit	72	215·5	175·5
Kantilu	94	165·5	135·5
Baidessur	107	140·5	110·5
Chirchika	115	129·5	87·5
Naraj	135	92·5	65·5
Kattak	144	77·5	55·5
Mouth of Katjuri, Jaipur	172	37·5	15·5
Mouth of Mahanaddi	200	5·5	0
Mean Sea Level	...	...	0

The Mahanaddi is navigable from Devighat near Sheonarain, a point where the river Sheonath joins it, to a point near Padampur, a distance of 60 miles. From Padampur, by Sambhalpur to Binka, above Sonpur, the river is unnavigable on account of rocks. From Binka to Kattak, 150 miles, most of the channel is navigable permanently throughout the year, the rest being navigable for less than half the year. From Kattak to the mouth the distance is about 60 miles; thus about 270 miles out of 450 are more or less navigable.

The Tributaries of the Mahanaddi.

Torrents.	Near village of.	Distance above Kattak. Miles.	Width of Mouth. Feet.	Nature of bed.	Nature of stream.	Fall of bed in feet per mile.
Kaligiri	Baidessur	37½	200	Alluvial.		
Komi	Kantilu	48½	320	Rocky above.		
Burtung	Bentpara	64¾	300	Sandy and rocky.		$6\frac{2}{3}$
Salki	Above Boad	120½	465	Ditto.	Perennial.	
Baj	Dayah	136	700	Ditto and very rocky.	Perennial	
Mirni	Lowpara	141	400	Sandy and rocky.		
Tel	Sonpur	143	3470	Ditto.	Perennial.	

The navigable upper tributaries are the Tel, for 150 miles out of 200; and the Sheonath, for 75 miles out of 195, up to Nandghat. The smaller affluents, the Hasdu, Mand, Kailu, and Ib are each navigable for about 20 miles from their confluences with the Mahanaddi.

The Mahanaddi and Katjuri have in high floods velocities of 7 feet per second. At Naraj the Mahanaddi emerges from a rocky ridge, only $\frac{5}{8}$ mile wide, into a wide basin, 3 miles broad and 4 miles long, reaching to Kattak. The head land of the delta at Naraj divides the Mahanaddi north of town from the Katjuri south of town. The upper affluents of the Mahanaddi are in hilly country, and may be said to be unexplored.

From gaugings at Kattak it appears that the ordinary embanked channels of the delta could only carry off a flood rising to 20 feet on the gauge, and half a flood rising to 27 feet—hence the devastation so often caused; a flood over $20\frac{1}{2}$ feet may last seven days, although they remain at full height for only 12 hours. There is a sounding of 80 feet of water in the bed between Baidessur and Dewakot, being $16\frac{1}{2}$ feet below mean sea level. The Banki reservoir covers an area of 150 square miles, having a mean flood depth of 20 feet, and gives one-third of the relief from flood that is required. Total flood discharge from 27th July to 3rd of August, 1855, 761 billion cubic feet; of which 545 billions can be carried off in the river channels, leaving 216 billions in 7 days=400 000 cubic feet per second to be provided for by reservoirs, cuts, and special arrangements.

Discharges of the Mahanaddi and Katjuri.

Date.	Place.	Cubic feet per second.
Flood of 1855 ...	Below junction with the Beropa ...	1 040 000
Flood of 1855 ...	The Katjuri and Kokai	780 000
	Mahanaddi Series, Total	1 820 000

The historian of this river is Captain Harris, who laboured many years in endeavouring to mitigate the effects of its floods.

In 1863, Mr. W. Armstrong recommended to Government the construction of a canal for 130 miles from Chandarpur to Dholpur, in preference to improving the bed of the river. The engineers of the East India Irrigation Company were then preparing

the project which took definite form in April 1864, for a canal combining irrigation and navigation, aided by storage reservoirs.

The Narbadda.—The peculiarity of this long river is its present unnavigable condition throughout the greater part of its course. There is no doubt that, in spite of all alleged difficulties, the most useful part of it could be rendered navigable.

It rises near Amarkantak, 5 000 feet above sea level, commencing a course of about 800 miles. In the upper reaches it runs in basalt, with falls, rocky barriers and rapids, and is utterly unfitted for improvement into a navigable course, until it arrives at Beira Ghat, opposite Jabalpur, about 500 miles from the sea and nearly 1 200 feet above sea level.

About this place the river enters its first upper-level large valley, about 200 miles long, from Beira Ghat to Hindea. In the first 120 miles of it, from Jabalpur to Hoshungabad, the fall is only 50 feet; thus the latter place is 1 150 feet above mean sea level.

The intricate navigation and impeded course extends between Hindea and Barwai; for this distance—60 miles—the fall from the first large valley to the second valley is nearly 400 feet; but the greater part of this fall is concentrated in 40 miles of it.

The second large valley commences above Barwai at a level of about 750 feet above the sea, and extends for about 100 miles to Chikalda, and has a general fall of nearly 200 feet.

Intricate navigation, falls, rapids, &c., commence near Chikalda, 583 feet above the sea, and extend to near Tallakwara, 250 feet above the sea; thus giving a fall of 333 feet in about 90 miles.

At Tallakwara the lowest or sea reach begins, and extends for 60 to 80 miles of tortuous course to near the town of Baroach and the sea.

Among the disadvantages met on this river are that—

1. The wind is generally against stream.
2. In the shallows there is only one foot of water.
3. The current is 4 miles an hour.
4. The mansun freshes rise to 70 and 90 feet.
5. The banks are very high in the level valleys.

Also that Captain Fenwick's journey in 1848, July and August, taking down 11 tons of Narbadda coal on the river, seems to have acted as a permanent deterrent instead of an inducement to improve the navigation of a district where marble, coal and iron were plentiful.

The Godavari, length 898 miles, rises at Nassik, lat. 20° 0′, long. 73° 47′, and passes south of Aurungabad, through native territory for 450 miles, until it joins the Pranhita at Sironcha. Above Sironcha it is unnavigable, and had a discharge in February, 1866, of only 300 cubic feet per second. From Sironcha to Palmilla, about 38 miles, the fall of the bed is 0·5 feet per mile, and this part of the river is navigable; the Pranhita having contributed a discharge of 726 cubic feet per second (February, 1866). From Palmilla to Enchampilli is a barrier of rock 14 miles long; known as the second barrier of the Godavari, above which the river is 3 900 feet wide. From Enchampilli to Dammagudiam 270 miles, the river has a fall of 1 foot per mile. At Dammagudiam there is a barrier of rock 8 miles long, known as the first barrier of the Godavari; at this place the river is 5 280 feet wide, the discharge being 1 875 cubic feet per second in May, and 9 375 cubic feet per second in January, having a current of 3 to 5 miles an hour. At Gollagudium, about 20 miles below this barrier, the discharge in February, 1866, was 2 825 cubic feet per second. At Palaveram the river emerges from the hills, 80 miles below the first barrier, and 20 miles from the town of Rajahmandri, which is 4 miles from Dowlaishwaram, the head of the delta: for these 104 miles the fall is about 0·5 feet per mile. At Palaveram the river gorge is only 600 feet wide (February, 1866), but the floods rise to 60 feet above the February level; very high freshes occur three times in the mansun and last for four or five days; the general velocity of the stream then being 6 miles an hour. The river is navigable from Sironcha downwards, excepting at the barriers, during the mansuns only, *i.e.*, from December to May. It has three unnavigable tributaries: the Indrawatti, joining it above the second barrier, which is 300 miles long, discharging 150 cubic feet per second (February, 1866); the Sibberi, 200 miles long, discharging 500 cubic feet per second (February, 1866), and joining it below the first barrier; and the Jal, 100 miles long.

From Sironcha to the first barrier the river channel has no permanence of form, it shifts its course, and forms large banks and shifting shoals; the banks are soft, and the rocks that occur are sandstones and sometimes limestones. From the first barrier to the head of the delta the channel is comparatively permanent, the banks are tough, the sand is large and coarse grained,

requiring a powerful current to displace it, the rocks are unstratified, and form natural groins, which aid in giving permanence to the channel. From the delta head downwards the river runs in a natural embankment, 6′ to 24 feet above the level of the country; its bed falls 0·5 feet per mile, the summer water surface 0·7 feet per mile, and the high flood surface 1·25 to 1·50 feet per mile, down to the mouth, 40 miles below. In the delta the river, when in full flood, has a width of 2¼ miles, and a surface velocity of 4½ miles an hour; the rise of surface varies from 20 to 50 feet; the last two feet of rise being never maintained for more than two hours. From the middle of June to the middle of September the volume is always more than 12 000 cubic feet per second; during the rest of the year 3 000 cubic feet per second is considered its ordinary minimum supply. In excessively dry years the discharges have been as follows: December, 16 875 cubic feet per second; January, 8 047; February, 3 825; March, 2 782; April, 2 047; May, 1 687; first half of June, 1 500 cubic feet per second.

The Tributaries of the Godavari.—These are first, the hill streams in the neighbourhood of Nasik; then the Prawara and the Mula from about Akola, which join it near Newasa. Above Nander, it is joined by the combined Dudna and Purna; and below Nander by the Manjira, which has a very tortuous course and drains a large tract. The Manair also joins it just above its confluence with the Pranhita.

The Northern Tributaries of the Godavari, that together form the Pranhita, which is 90 miles long from Tallodhi to Sironcha, are the Warda, 250 miles long, which rises in the Satpura range, and after being joined by the Wunna at the falls of Dindora becomes navigable for the last 100 miles of its course; the Painganga, which rises in the hills south of Berar, and after an unnavigable course of 320 miles, joins the Warda above Chanda; and the Wainganga, which rises in the Satpura range near Seoni, takes a course of 430 miles, unnavigable, and joins the Warda at Tallodhi. The Pranhita is, like the lower portion of the Warda, navigable for three months in the year, from Tallodhi to Dewalmarri, where there is a barrier of rock 36 miles long; below this to Sironcha it is navigable for four months. The fall of its bed is about 1 foot per mile, so also is that of the Warda in its

navigable portion. Above this the Warda falls 4 feet per mile, and the Wunna 2 feet per mile. The Wainganga has a fall of 546 feet in 192 miles, from Kampti to its mouth, or 2·8 feet per mile.

In 1864–67 an attempt was made by Col. Haig, aided by Captains Roberts and Jackson, to open a navigable communication from Dindora to the coast; it was, however, at last abandoned, on account of its excessive expense.

The Kistna, length 800 miles, rises north of Sattara, Bombay presidency, in latitude 18°, and enters the sea 35 miles S.W. of Masulipatam. It is a perennial river, entering the plains at 80 miles from its mouth, and there becoming a large river, is utilized in deltaic irrigation. In the dry weather, from November to June, its supply is very small, being derived principally from springs in its bed; from July to October it varies much, even falling as much as 10 feet in 24 hours. In full mansun there is a constant stream 20 feet deep, the crest of its banks is from 20 to 40 feet in height, and its section from $1\frac{3}{4}$ to $2\frac{1}{4}$ miles broad. At Bezwara, the head of the delta, 60 miles from the sea, where are the last outlying spurs of the hills and the anicut or dam, the river is 1 300 yards wide, and has a depth in dry seasons of from 5 to 6 feet, in average freshes of 31, and in highest freshes of 38 feet. In the delta it runs on an elevated ridge, having an average fall to the sea of 1 foot per mile, varying from 0·9 to 1·1 feet; the fall of the country on both sides towards the sea being 1·5 feet per mile. The irrigation of the delta, commenced by Captain Orr, provides for taking off 3 500 cubic feet per second for each side of the river; but the irrigable area on each bank is capable of utilizing 32 000 cubic feet per second during the season of cultivation.

The Tributaries of the Kistna.—The Upper Kistna, or Krishna, in Satara, is joined by the Koyna near Kanad, afterwards by the Yerla and the Warna, above Miraj; two other affluents join it near Kurundwad. After a tortuous course it is joined by the Ghatparbha, near Bagalkot, and the Malparbha, with its tributary, the Nawalgund Stream, at a point near Hungund; these two rivers, from Belgaum and Dharwar, being of torrential character.

The large affluent, the Sina, joins the Kistna near Raichur; the other large affluent, the Tungabaddra, joins it below Karnúl. There are several lower tributaries from the north, the chief being the Musi and the Muniyer, which have large catchments in

Haidarabad territory. The following are the falls in feet per mile on these tributaries :—

The Krishna, Sattara,		*The Koina*,	
above Kursi ...	4·7	Helwak to Karrar ...	1·3
Kursi to Bahey ...	1·9	Karrar to Bahey ...	0·4
Bahey to Yerla ...	1·4	above Bamnoli ...	6·0
below Yerla ...	0·6	*The Malparba*, Belgaum	1·25 to 1·5
The Yerla,		*The Gatparba*, Belgaum,	
Krishna to Chikli ...	8·8	below Gokak ...	1· to 2·

The Sina affluent.—The Bhima rises in the Ghats above Khed; after being joined by several hill streams in that neighbourhood, the Mulamutha, from Puna, joins it, also the Ghornaddi, or combined Ghod and Kukari, near Dhond. The Nira, a large stream from Bhor, joins it below Indapur; the Man joins it near Mangalvedha, and last it joins the Sina proper in the neighbourhood of Sholapur.

The Upper Sina, or Sina proper, rises near Ahmadnagar, and follows a very direct course, with few affluents, by Purainda and Sholapur.

The combined Sina-Bhima is joined near Wadi by a large affluent composed of the Mulamari, the Benathora, and other streams from near Pargi; the whole flows south to join the Kistna opposite Raichur.

The following are the falls in feet per mile on these tributaries :—

The Nira, Puna,		*The Sina*, Sholapur,	
above Ramlishwar	4·6	above Undogaum ...	2·75
The Indarauni, Puna ...	2·75	*The Man*,	
The Bhima, Puna,		Diguchi to Manswar ...	5·5
Sarwali to Deksal ...	2·75		

The Tungabaddra affluent has a length of about 213 miles from Gutal, where its upland tributaries, the Tunga, the Baddra, and the Choardi join the Warda, to its junction with the Kistna, at about 81 miles below Karnul. These four upland tributaries drain an area of 3 754 square miles in the province of Maisur, a portion of which is hilly country, having a downpour of 135 inches, the remainder being plains with a downpour of only 24 inches.

Of these, the Warda, draining 610 square miles, has merely a few small anicuts on its feeders; its ordinary mansun discharge is roughly assumed to be 5 000, and its maximum flood discharge

30 000 cubic feet per second. The fall of the Warda in Dharwar is 2 feet per mile.

The Haggri—joined by its affluent, the Chinna Haggri, which falls into it near Mukalmuru—feeds the large Eyenkaira and Maddak tanks in a comparatively rainless district, and may eventually also supply an intended large reservoir at the Mauri Kunawai pass, where its discharge has been gauged for two years, giving as an ordinary mansun discharge 4 500 and as a maximum flood discharge 50 000 cubic feet per second.

The Tunga, after being joined by the Baddra at Kudli, is joined by the Choardi at 10 miles above Harihar, and at Harihar itself by the Sulikerri; the maximum flood discharge of the combination of the three at the large bridge at Harihar has been determined to be 207 843 cubic feet per second, and the ordinary mansun discharge roughly calculated to be 30 000.

At Wallabapur, after a course of 55 miles, the Tungabaddra is joined by two tributaries, and at its 120th mile by the Haggri, after which it passes Sunkesala at its 175th mile, and Karnul before joining the Kistna. The fall of the Tungabaddra in Dharwar varies from 2 to 2·5 feet per mile. At Sunkesala are the headworks of a series of canals flowing thence to Kaddapa; and Wallavapur is the proposed site of headworks for a high-level canal, thence passing Ballari to Karnul. In order to afford further supply to these canals, it was proposed to enlarge existing reservoirs and make others on the upland tributaries of this river; and with this view some gaugings were made on them for six months from June to November, 1865, giving the following results:—

	Sq. miles.	Million cub. ft.	Inches run off.
The Tunga, at Shemuga ...	950	229 662	108
The Baddra, at Benkipur ...	884	125 928	63
The Choardi, to Maddak tank	486	54 000	50 in floods.
The Haggri, at Heriur ...	1 400	1 350	
The Tungabaddra, at Wallabapur		356 940	
The Tungabaddra, at Sunkesala		569 700	

The proposed reservoirs on the tributaries, intended to store the above supplies, and render the present Tungabaddra canals perennial, are the Mudaba on the Tunga, the Lakkawali on the Baddra, the Masur on the Choardi, and the Mauri Kunwai on the Haggri.

Further information about the upland tributaries in Maisur is given in the following tabular data:—

The Kistna Tributaries in Masiur.

RIVER SYSTEM.	Feeders in Maisur.	Length in Maisur.	Area over which the drainage is unintercepted in tanks in Maisur.	Area over which the drainage is intercepted by tanks in Maisur.	Total area of catchment basin.	Percentage of whole area under tank system.	Rises at	Falls into
		Miles.	Sq. miles.	Sq. miles.	Sq. miles.	Per cent.		
Kistna ... (Falls into Bay of Bengal in lat. 15° 45'.)	Warda ...	47	430	180	610	29·51	Sagar; it has a few minor anicuts, but may be further utilized.	River Tungabaddra, 35 miles below Harrihar.
	Choardi ...	43	None	510	510	100·00	N.E. of Kaulidrug; it has a few minor anicuts, but may be further utilized.	River Tungabaddra, 10 miles above Harrihar.
	Tunga ...	149	1 287	100	1 389	7·25	Gangamula, lat. 13° 15'. Many anicuts on feeders.	Kudli, 10 miles N.E. of Shemogah.
	Baddra ...	160	1 500	175	1 675	10·50	Do. Many anicuts on feeders. Proposed Lackawalli reservoir.	Do.
	Sulikerri ...	45	231	799	1 030	77·60	S. of Chennagherri, feeds the Sulikerri tank.	River Tungabaddra at Harrihar.
	Chinna Haggri	53	168	356	524	67·90	(Not given.) Might be utilized; feeds the Haggri.	N.E. of Mulkalmora, Ballari.
	Haggri or Vedavatti, Yerahalli	114	1 198	4 097	5 295	77·37	Bababudin Hills, lat. 12° 30'; feeds Eyenkaira and Maddak tank, also the Mauri Kunwai site; should be further utilized.	River Tungabaddra, 55 miles above Sunkesala.
Total of the Kistna System.	...	611	4 814	6 217	11 031	56·47		

The Penner, length 355 miles, rises in Maisur, about 150 miles above the Madras Railway bridge, down to which point its catchment area is 4 500 square miles. At Perur, where its upland tributaries have joined it, the channel is larger and more permanent; from this point its course is about 110 miles in length, without having any important tributary, to its junction with the Chittravatti above Jamalmagdu, where the catchment area of the latter stream is 3 325 square miles: the maximum flood discharge of the Chittravatti is 23 100 cubic feet per second, and its ordinary mansun discharge is about one-tenth of that. About 40 miles below this its tributaries, the Kunder and the Papagni, rejoin it, the one having a catchment area of 3 000, the other of 2 460 square miles: the latter has a maximum flood discharge of 5 244 cubic feet per second, and an ordinary mansun discharge of about one-tenth of that. At 32 miles below this the Sugaler and the Cheyer join it. At 18 miles below this, and at 70 miles from its debouchment into the sea, is Someshwaram, where the river leaves the Western Ghats, the site of the proposed headworks for a deltaic canal to irrigate the Nellur side of the delta. The total length of the river from Perur to the sea is about 270 miles. Its upland tributaries in Maisur are utilized (see following tables of the tributaries), but for the rest of its course down to the head of the delta the river now flows on unutilized. On the Kunder, at 25 miles above its junction with the Penner, is the Rajoli Dam and subsidiary headworks of the chain of canals from Sunkesala to Kaddapa; the tributaries of the Kunder are also utilized in the same way, affording irrigation to the large valley of the Kunder.

For the greater part of the year the Penner, as low even as the Madras Railway bridge, is dry at the surface, though at from 1 to 4 feet in the bed plenty of water can always be found. The ordinary mansun floods are 6 to 8 feet deep; the extraordinary floods, 13 feet. At the bridge-site the river is 1 550 feet wide; the soil is clay for 5 feet, gravel mixed with clay and kunkur nodules for 4 feet more, resting on a layer of sand, superimposed on hard, dark green kunkur.

The Palar has its upland course in Maisur (see tabular data); its lower course in Madras is not described in any available official account. It has a long narrow basin.

The Tributaries of the Pennar, Palar, and S. Pennar, in Maisur.

River System.	Feeders in Maisur.	Length in Maisur.	Area over which the drainage is unintercepted in tanks in Maisur.	Area over which the drainage is intercepted by tanks in Maisur.	Total area of catchment basin.	Percentage of whole area under tank system.	Rises at	Falls into
		Miles.	Sq. miles.	Sq. miles	Sq. miles.	Per cent.		
Pennar ... (Falls into the Bay of Bengal in lat. 14°37'.)	Gandacholli or Jimangal ..	60	185	452	637	77.96	Davroydrug, Tomkur ; not used now, might be utilized.	
	Upper Penner...	36	149	501	650	77.08	North of Nandidrug ; not used, might be utilized.	
	Kushawatti ... Chittravatti ... Papakenni ...	16 23 32	None.	993	993	100.00	All rise in north of Kolar Division ; feed Darmavaram tank, the Kuchru tank, and Gudibunda large tank.	
Total of the Pennar System ...	...	167	334	1 946	2 280	85.35		
Palar ... (Falls into the Bay of Bengal in lat. 12°27'.)	Palar	47	None.	1 036	1 036	100.00	Chintamanipett Kolar ; this is entirely utilized by tanks in Maisur.	Enters Madras territory at Gumsur.
S. Pennar ... (Falls into the Bay of Bengal in lat. 11°25'.)	Verushavatti ...	18	135	259	394	65.75	In Kolar ; not likely to be further utilized.	Joins the Penankenni.
	Penankenni ...	14	87	1 060	1 147	92.41	NE. of Nandidrug ; feeds five large tanks ; would not be further utilized.	Pasess Urkattah.
Total of S. Pennar System...	...	32	222	1 319	1 541	85.60		

The Kavari, length 472 miles, rises in the Western Ghats, and has a catchment area, together with its delta, of 32 000 square miles. It is fed by both mansuns, and its volume is abundant from the beginning of June to the end of December. The discharge on the 4th December, 1833, at the head of the delta, was 16 875 cubic feet per second, according to Col. Cotton: but in high flood the discharge is as much as 320 625 cubic feet per second. These discharges represent respectively 0·53 and 2·85 cubic feet per second per square mile of catchment; the latter being 75 per cent. of the estimated downpour, or a depth of 0·60 feet run off annually.

From January to May the discharge is small, much less than 16 000 cubic feet per second; though there are freshets in March and April due to local storms. Above Srinagram, in Tanjor, the Kavari divides itself into the Kavari and the Kalerun branches, which irrigate the delta, none of the Kavari water reaching the sea in dry seasons; this is due to the grand anicut of Srinagram constructed by the Telinghi rajas in remote antiquity, and restored and remodelled by Col. Cotton, between 1830 and 1836. The slope of the main stream above the bifurcation is 3·5 feet per mile; from that to Srinagram, that of the Kalerun is 2 feet per mile; from Srinagram to the sea coast, its average slope is 1 foot per mile. The general fall of the main Kavari branch is 0·4 feet per mile less than that of the Kalerun. Before 1830, 12 622 cubic feet per second were utilized in irrigation from the Kavari branch and 4 125 cubic feet per second from the Kalerun, or 16 474 cubic feet per second in all, out of 16 875. In 1833, the works constructed by Col. Cotton utilized 9 375 cubic feet per second from the Kavari and 7 500 from the Kalerun, the latter suffering as much from excess as the former from deficiency. In 1845 Col. Sim made a regulating dam across the head of the Kavari, and lowered the Kalerun dam 2 feet, since when the regimen has been perfectly under control. The Kalerun is now not only a channel of irrigation, but is also the great drainage channel of the delta; the Kavari is a channel of irrigation only, its entire volume being subdivided into small channels, and entirely utilized, although in its upper portion it is a mile in width. Information about these works is given under the head of the Kalerun deltaic canals.

The Tributaries of the Kavari, consisting of the Upper Kavari the Somavatti, Hemavatti, Lachmantirth, and Lokani, join above Sriringapatam. Their combined maximum flood discharge at Bannur, below that town, has been roughly determined to be 239 000 cubic feet per second; the ordinary mansun discharge, for a depth of 8 feet, is about 36 000 cubic feet per second. The other tributaries are the Kabbani, the Arkavatti, and the Shimsha; the maximum flood discharge of the Kabbani at Nanjengod is calculated to be 63 700 cubic feet per second, its ordinary mansun discharge about one-tenth of that; the maximum and ordinary mansun discharges of the Arkavatti at the Mangadi-road bridge are calculated to be 50 000 and 3 500 cubic feet per second; the discharges of the Shimsha are assumed to be identical in quantity with the latter. Some further information about these tributaries in Maisur is given in the tabular data.

The Tributaries of the Kavari, in Maisur.

River System.	Feeders in Maisur.	Length in Maisur.	Area over which the drainage is unintercepted in Maisur.	Area over which the drainage is intercepted in Maisur.	Total area of catchment basin.	Percentage of whole area utilized.	Rises at	Falls into
		Miles.	Sq. miles.	Sq. miles.	Sq. miles.	Per cent.		
Kavari ... (Falls into the Bay of Bengal in lat. 11°55'.)	Upper Kavari...	171	1 201	750	1 951	38·44	Tallakavari, lat. 12° 25'; has large anicuts on it, which require improvement.	Passes Tulkad.
	Surnavatti ...	23	185	None.	185	0·00		
	Hemavatti ...	107	630	662	1 292	51·25	E. of Bellariadrug, lat. 13°10'; has large anicuts on it: no tanks.	Kavari near Yedatur.
	Yegachi ...	37	375	145	520	27·90	S. of Bababudin hills; feeds Chikmanglur tank, and some anicuts.	Joins the Hemavatti.
	Lachmantirth...	64	487	175	662	26·44	Brammeagherri, lat. 11° 55'; has many anicuts; no tanks.	Joins the Kavari.
	Lokani ...	27	80	95	175	54·30	Supplies a large tank; the Motit also.	Northern feeder of the Kavari.
	Kabbani ...	80	843	784	1 627	48·18	Lat. 11° 55'; its feeders supply large tanks and anicuts, to be further used.	Kaveri, 12 miles above Tulkad.
	Shimsha ...	73	585	2 639	3 224	81·85	Has large tanks and anicuts; from Gandestri to Tomkur, but might be further utilized.	Kavari at Sivasamudram.
	Arkavatti ...	63	1 140	519	1 659	31·30	At Nandidrug; has five tanks and some ruined anicuts.	
Total of Kavari	System in Maisur...	645	5 526	5 769	11 295	51·75		

The Western Coast Rivers in Maisur.

River system	Feeders in Maisur.	Length in Maisur.	Area over which the drainage is unintercepted in tanks in Maisur.	Area over which the drainage is intercepted by tanks in Maisur.	Total area of catchment basin.	Percentage of whole area under tank system.	Rises at	Falls into
		Miles.	Sq. miles.	Sq. miles.	Sq. miles.	Per cent.		
Western Coast Rivers.	Garsappa or Sheravatti... ...	49	1 101	None.	1 101	0·00	Supplies a few channels in Maisur.	The Sea at Honawar.
	Nartravatti ...	6	...	...	...	...	... ...	The Sea at Mangalur.
	Puiswanni ...	12	780	None.	780	0·00	All rise to the west of the Ghats, are useless to Maisur.	
	Komardari ...	16	...	...	...	...		The Netravatti.
	Other names not given	20						
Total of Western Coast System in Maisur		103	1 881	None	1 881	0·00		
Total for the rivers of Maisur and Kurg		1 606	12 777	16 287	29 064	56·16		

The Tambrapurni, length 80 miles, rises in the Western Ghats, having its principal source in the valley of Papanassan, drains a large tract of hilly and woodland country under the influence of both mansuns, and falls into the sea south of Tuticorin. Its catchment area is 200 square miles; its course for 20 miles is in forest-covered mountains, where the annual rainfall is from 200 to 300 inches; and for 70 miles in plains at the foot of the hills, where the rainfall is from 20 to 30 inches; for the remainder of its course it receives a rainfall of only 18 inches. Its fall at Papanassan, and that of its tributary, the Chittar, at Kurtallam, are renowned for their beauty, and are considered sacred. There are seven native anicuts on the Tambrapurni, four on the Chittar and two on the Mannemubuar: in addition to the modern one constructed at Strivigantam by the English. Its floods commence in June, when they are sometimes 10 feet deep, and frequently recur during the next six months, or during the north-east mansun. The drainage from the hills keeps up a stream, at Strivigantam, of about 314 cubic feet per second, in the hot weather, and of never less than 198 cubic feet per second in March; during the six months of full supply the discharge is not less than 600 cubic feet per second. The amount of its discharge utilized for irrigation is thus estimated in the Government records:—

864	cubic feet	per second,	for 225 days	for 1st crop.
405	"	"	for 45 days	for 2nd crop.
$192\frac{6}{8}$	"	"	for 45 days	for 2nd crop.

Average depth at Strivigantam 7 feet, fall $2\frac{1}{2}$ to 3 feet per mile, velocity 5 to 5·6 feet per second.

The Vaipar.—The discharge of this stream has not been measured, nor are any observed velocities mentioned in the Madras Government records, but its flood discharge has been thus approximated to by calculation. Its catchment area is 342 square miles, and it is supposed that there is a maximum rainfall in 24 hours of 8 inches over one fourth of it, of 4 inches over another fourth, and of 2 inches over the remainder, and that the stream carries off one-fourth of this, three-fourths being lost by absorption and evaporation. This gives a flood discharge of 8 850 cubic feet per second.

Burma.

The Irrawaddi.—Discharges were measured at Saiktha from July, 1872, to September, 1873. Below this the floods pass over the left bank into the Rangun branch. Formerly some went over the right bank into the Nawoon river or Bassein branch.

Between the years 1870–77, the least annual discharges occurred in 1873 and 1876; and the greatest annual discharges in 1871, 1875, and 1877.

An average discharge throughout a year is at 469 040 cubic feet per second.

The low-water period is from December to May ...	12½	per cent.
High water „ June to November ...	87½	„
	100	„

High flood happens in July, August, or September. Mean flood does not exceed 1 200 000 cubic feet per second at Saiktha.

	Cubic feet per second.
Least measured discharge at Saiktha on 3 March, 1873	79 000
Least estimated discharge 5 March, 1877	46 000
Greatest „ „ on 20 Aug., 1877	2 000 000

The Irrawaddi is 3 to 4 miles wide near Mandalay above the influx of its lower tributaries. The measurements of Heathcote, at Sagaing, 3 miles below Mandalay, in October, 1854, gave 316 580 cubic feet per second, at a section of 105 300 square feet in ordinary flood.

At Bhamo, 800 miles from the sea by river course, the river is 1½ mile wide in flood, and 1 mile at low water; but it is broken into three channels by islands; the rise from low to high water is 60 feet. The estimated high flood discharge is 1 200 000 cubic feet per second.

At the Tshenbe defile, 5 miles above Bhamo, there are rapids and rocks; here navigation for steamers ends. The Mogoung tributary enters above the defile. This defile is about 20 miles long, and at one point is only 180 feet wide; its depth varies

from 11 to 25 fathoms; and its current is 12 to 15 miles an hour when not near the highest stage.

At the Muntgoung defile (lat. 26° N.) Mr. Thettell, in February, 1874, found the river divided into two branches, one 150 feet wide, the other about double that, with 6 feet of water in the deepest part; this narrowed to a gorge just below Muntgoung, the highest point reached yet by any European.

Tributaries of the Irrawaddi.—The four affluents, mostly navigable for large vessels, are the Ringthi, the Mogong, the Bhamo, and the Lungtchung. Their depths are tolerably uniform; the tide is not excessive, though it comes in with a rush; there is not a bore as on the Salwin.

Table of Flood Levels in the Irrawaddi.

Places.	Distances.			Water Level above M.S.L. of 1877.				
	From Saiktha by bank.	From Saiktha by river.	From sea by China Baker river.	At low water, 1877.	Floods of 1868.	Flood of 1871.	Flood of 1875.	Flood of 1877.
	Miles.	Miles.	Miles.	Feet.	Feet.	Feet.	Feet.	Feet.
Saiktha	0	0	230	39·42	—	—	77·86	79·74
Myanoung ...	13	15·5	214·5	30·18	68·47	70·15	70·91	71·87
Kanoung	20	22·7	207·3	—	66·19	67·23	68·07	—
Shwaygyeen..	31	35	195	20·01	59·55	60·50	61·34	62·09
Nyoung Yo ...	45	51	179	14·44	52·07	53·77	53·77	54·10
Loodanzoo ...	50	63·5	166·5	—	—	49·02	—	—
Nawoon*	61	72	158	—	—	44·76	45·70	—
Henzada	69	84	146	5·46	41·19	42·48	43·48	43·78
Zaloon	86·5	101	129	2·99	—	35·47	35·99	36·41
Donabyo	112	130	100	0	—	—	24·47	24·43
Setkaw	125	144	86	0	—	18·89	19·00	—
Baudee†	138	165	—	0	—	—	10·99	—

* This is at 1 mile down the Nawoon river. † This is at 13½ miles down the Patanaw river.

The Sit Toung.—This river has a long, narrow basin between the Irrawaddi and the Salwin; the main channel passes by the towns of Tounghoo and Sit Toung.

The Salwin or Nukiang, also called the Mulmen river.—Dr. Richardson visited this river on 14th February, 1837, crossing it

in latitude 18° 16′ 22″, at about 200 miles from its mouth; it was there 900 feet wide, its rainy season channel being double width, with steep banks; having a probable highest flood discharge of 600 000 cubic feet per second. He reported the river unnavigable beyond 60 or 80 miles from its mouth. Sconce and Watson examined the river on 30th December, 1863, in latitude 18° 50′, and found the channel and probable discharge there corresponding to the data of Richardson. O'Riley visited the rapids between those two points, where the river was compressed to 360 feet wide, and blocked with boulders and shingle; unfit for navigation, except when the river is full and for a short time.

Davenport crossed the Salwin on 30th April, 1876, by an iron suspension bridge, of two spans of 500 feet in all, on the high road from Bhamo to Yunan. The span over the deep bed was 270 feet wide; the stream was deep, rapid, and turbid.

This river has a long, narrow basin without any large lower tributaries; it is much broken by cataracts, and is subject to a bore, sometimes 20 feet high. Its length is unknown. The eastern bank of much of the main stream is Siamese territory.

The Me Khlaung and the *Me Nam* are in Siamese (Thai) territory, and have not been explored.

The Me Kong is the great river of the Burmese peninsula, with an enormous delta in Camboja.

The Song Kai is the most eastern river of this peninsula.

These four latter rivers drain eastwards and have been but little explored.

CANALS.

LIST OF NAVIGABLE CANALS OF INDIA, CONSTRUCTED OR IMPROVED BETWEEN 1848 AND 1859.

NORTH-WESTERN INDIA.

PANJAB.

There is not any navigable canal yet open, in 1859.

The Bari Doab Canal, under construction, is a navigable channel for 469 miles, having cost £620 000. The sum of £730 000 will be required to complete it.

SIND.

Karachi Collectorate.

The following old canals have been improved, and are suited to country boats only during the inundation period, from June to August :—

	Miles.	Cost.
Khanani Canal	3·5	
Makri Canal	4·75	
Makri and Nasirabad and Khanani	13·5	
Chandan, Khanani and Makri	7	
Mahmudwah Panyari and Shorwah, Chandan and Satah	15·25	
Satah Chandan, Shorwah, Mahmudwah, Panyari and Shorwah	10	
Nasirabad and Makri Fattah	7	
Satah and Khunta	5·5	
Azul Canal to the Indus (perennial)	10·	
Fattah	1·75	
Nine canals in Jerrak and Shah Bandar districts ...	51·0	
Haidarabad Collectorate.		£
New Sangatwah Canal expenditure	0·75	128
Shikarpur Collectorate.		
Biggari Canal	75·	17 000
Nurwah Canal	19·	2 300
Total in Sind	224·	22 109

	Miles.	Cost.
NORTH EASTERN INDIA.		
NORTH-WEST PROVINCES.		
The Western Jamna Canal. / The Eastern Jamna Canal. / The Ganges Canal, open in 1854. — Not much used for navigation.		
BENGAL.		
The following are tidal canals :—		£
Uttadangah Canal from Dhapah to Uttadangah ...	4	7 208
Canal from Kaurapukar Thal to Charrial Khal ...	8	749
	12	7 957
SOUTHERN INDIA.		
BOMBAY (*Malabar*).		
In this presidency, excluding Sind, there are not any navigable canals.		
MADRAS.		
Rajahmandri District.		
Improvement of Upper Godavari ; spent		14 052
Estimate for half a million pounds to make the river navigable as far as Berar cotton districts ...		
Palkol Channel, from Dauleshweram to Narsapur, to serve for navigation and irrigation	30	16 138
Thubah Bagah Channel from Taddam to Kokanada ; navigable and irrigating	26	38 082
The Ralli Channel	28	14 551
The Samulkottah Channel, with extension to Tuni ...	28	11 902
Masulipatam District.		
High level Channel, from the Godavari anicut to Ellor ; this will be extended to Bezwada	38	19 248
The Apprau Channel, to the right of the Godavari ...	7	8 481
The Bodemer Channel	23	8 955
The Weyleru Channel	29	24 235
The Puleru Channel	32	17 663
The Mopedani Channel	22	4 556
Gantur District.		
The Tumbaddra Channel	40	7 660
The Mizamapatam Channel	32	16 260
Extension of the High level Channel to Niganampad, joining the East Coast Canal.		
Carried forward ...	335	£196 783

	Miles.	Cost.
Brought forward ...	335	£196 783
South Arkot District.		
Improvement of the Khan Sahib Channel	20	576
Canal from Kaddalur harbour to Porto Novo on the river Vellur	11	10 628
Tanjor District.		
Canal from Trimulvassel on the Umbenam to the Kalerun river	10	4 227
Improvement of the Maniar river	36	3 500
Malabar District.		
Canal between Punani and Teruvangaddi	12	514
Opening the Kalikut Canal	8	1 936
Canal from the south bank of Punani river to the backwater	12	1 450
From the Puraparamba lake to the Tanur Canal	2	838
Madura District.		
Improvement of the Paumben Channel	3	5 059
Eastern Coast Canal.		
Eastern Coast Canal	62	31 685
The whole now open for traffic is 174 miles. The entire length will be 588 miles from Tuni to Point Kalamir.		
Total for Madras Presidency ...	512	£257 196

Remark.—With the exception of the rudimentary East Coast Canal and some of the Rajahmandri and Masulipatam channels. these Madras canals are suited to local traffic, having a depth seldom exceeding 4 feet.

BRITISH BURMA.

Tenasserim and Martaban Provinces.		
Canal across a bend in the river Sittang below Shoay Gyin; navigable but not completed	0·28	75
Canal from Dannu to the Sittang; and Zamathway	85·00	600
creek, open for steam traffic from June to October	17·	30
Total for Burma	102·28	705
Total for India and Burma in 1859 ...	850·	£287 967

A List of the Principal Canals of India, Existing in 1874.

Northern India.

Perennial Canals fully Developed.

Name.	Province.	Source.	Supply, actual or intended. C. ft. per. sec.
The Western Jamna Canal ...	Panjab ...	The Jamna ...	2 372
The Eastern Jamna Canal ...	N.W.P....	The Jamna ...	1 068
Half Developed, or undergoing Re-modelling.			
The Ganges and Lower Ganges Canals		The Ganges ...	5 100
The Bari Doab Canal ...	Panjab ...	The Ravi ...	2 201
The Dun Canals	N.W.P. ...	... ...	123
The Rohilkand Canals ...	N.W.P. ...	... ...	unknown.
Under Construction.			
The Sarhind Canal	Panjab ...	The Satlaj ...	3 000
The Agra Canal	N.W.P....	The Jamna ...	2 000
The Sohan Canal	Bahar ...	The Sohan ...	5 300
The Sakhar Canal (Sind)		The Indus ...	unknown.
Inundation Canals.			
The Upper Satlaj Canals ...	Panjab ...	aggregate length	224 miles.
The Lower Satlaj Canals ...	„	„	418 „
The Chenab Canals... ...	„	„	222 „
The Jhelam Canals ...	„	„	unknown.
The Indus Canals in the Panjab	„	„	577 miles.
The Indus Canals in Sind ...	Sind	„	about 500 „

Southern India.

Perennial Canals (not completed.)

			Supply.
The Orissa Canals	Orissa ...	The Mahanaddi	various.
The Tungabaddra Canals (not yet rendered perennial)		...	3000
Minor Canals of Bombay in Kandeish, Sattara and Ahmadnugar.			
Deltaic or Inundation Canals.			
The Godavari Canals ...	Delta ...	aggregate length	269 miles
The Kistna Canals	Delta	„	225 „
The Pennar Canals	Nellur	„	unknown.
The Palar Canals ...	North Arkat	„	unknown.
The Kavari Canals	Tanjor	„	200 miles.

Channels from anicuts in Maisur.

Channels from anicuts in Madura and Tinnevelli.

LIST OF THE PRINCIPAL CANALS OF INDIA IN 1882-3.

NORTH-WESTERN INDIA (*Indus basin, &c.*).

Canals.	Province.	Supply.
The Western Jamna Canal ...	Panjab	Jamna.
The Bari Doab Canal	Panjab	Ravi.
The Sarhind Canal	Panjab	Satlaj.
Lower Satlaj and Chenab ...	Panjab	Satlaj, &c.
The Upper Satlaj Canals ...	Panjab	"
The Indus Canals of the Panjab	Panjab	Indus.
The Jhelam Canals	Panjab	Jhelam.
Minor Canals of the Panjab ...	Panjab	Various.
The Indus Canals of Sind ...	... Sind ...	Indus.
Háthmati Canal, Ahmadabad ...	...Guzrat ...	Háthmati.

NORTH-EASTERN INDIA (*Gangetic basin*).

The Eastern Jamna Canal	North-West Provinces	Jamna.
The Ganges Canal ...	North-West Provinces	Ganges.
The Lower Ganges ...	North-West Provinces	Ganges.
The Agra Canal ...	North-West Provinces	Jamna.
The Sardah Canal	Oudh, &c. ...	Sardah.
The Eastern Ganges Canal	Gogra-Ganges Doab ...	Ganges.
Minor Canals in the Dún, Rohilkhand, and Bijnaur ...		Various.
Bandalkhand Canals	Bandalkhand, &c.	Betwa.
The Sohan Canals	Bahar ...	Sohan.
The Midnapur Canals	Bengal ...	Hughli.

SOUTHERN INDIA (*Peninsula*).

The Orissa Canals	Orissa	Mahanaddi.
Bombay Canals	Kandesh, Sattara, &c.	Small rivers.
The Tungabaddra Canal	Karnúl, &c. ...	Tungabaddra.
The Godavari deltaic Canals ...	Delta ...	Godávari.
The Kistna " " ...	Delta ...	Kistna.
The Pennar " " ...	Nellur ...	Pennár.
The Palar " " ...	North Arkat ...	Palár.
The Kávari " " ...	Tanjor ...	Kávari.
Minor Canals in Maisur	Maisur ...	Small rivers.
Minor Canals in Madura	Tinnevelli, &c.	Vige, &c.

General Statistics of Canals in Northern India.

Abstract of General Results for 1860–61.

Canals.	Capital Account to 1st April, 1861.	Gross Income.	Charges and Maintenance.	Acres Irrigated.	Value of Crops Irrigated.
NORTH-WESTERN INDIA.	£	£	£	Acres.	£
Panjab.					
Western Jamna Canal † ...	168 687	46 334	22 084	494 252	—
Bari Doab Canal (in progress)	—	—	—	—	—
Sind.					
See details for 1859 at p. 285.	—	—	—	—	—
NORTH-EASTERN INDIA.					
North-West Provinces.					
Ganges Canal	1 874 828	64 511	128 898	342 909	1 512 264
Eastern Jamna Canal ...	141 350	27 610	17 430	261 327	954 705
Dun Canals	43 794	1 492	3 376	6 067	32 788
Rohilkhand Canals	19 830	3 667	3 274	91 995	—
Bengal.					
See details for 1859 at p. 286.	—	—	—	—	—

† This Canal is mostly in the Gangetic basin; but was transferred to the Panjab province, which includes this tract of country, in 1861 or 1862.

† This Canal is mostly in the Gangetic basin; but was transferred to the Panjab province, which includes this tract of country, in 1861 or 1862.

GENERAL STATISTICS OF CANALS IN OPERATION.

Abstract of General Results for 1872–73.

Canals.	Capital Account to 1st April, 1873.	Gross income in 1872-73. Direct.	Gross income in 1872-73. Total.	Working expenses in 1872–73.	Per-centage of profit or loss.	1872-73. Acres irrigated.	1872-73. Value of irrigated crops	No. of days the Canal was open.
NORTH-WESTERN INDIA.								
The Panjab.	£	£	£	£			£	
Western Jamna Canal ...	311 693	95 362	132 618	40 118	31	351 820	1 487 905	310
Bari Doab Canal ...	1 344 957	63 468	81 786	31 570	4	228 796	913 706	325
Upper Satlaj Canals ...	44 292	6 707	9 498	12 496	6	135 349	409 059	305
Lower Satlaj and Chenab	10 520	12 942	34 272	16 362	173	242 504	153 222	260
Indus Canals	43 736	7 866	15 960	18 046	−5	180 137	490 252	145
Shahpur Canals (Jhelam)	2 122	698	698	434	12	4 445	1 349	—
	1 757 320	187 043	274 832	119 026	8·9	1 243 051	3 455 493	
NORTH-EASTERN INDIA.								
North-West Provinces.							Charge for interest.	
Ganges Canal	2 605 178	158 992	186 660	98 871	3·4	685 170	116 660	244
Eastern Jamna Canal ...	206 177	56 253	68 561	21 918	22.7	184 154	9 310	337
Dun Canals	57 253	4 791	5 265	2 504	4·9	14 002	2 544	—
Rohilkhand Canals ...	103 601	2 438	5 699	5 132	0·7	55 650	4 121	—
	2 972 209	222 474	266 185	128 426	4·7	938 976	132 635	
Bengal.								
Midnapur and Tidal Series	695 812	3 544	9 805	9 621	0	13 406	41 202	—
SOUTHERN INDIA.		Navigation.						
The Orissa Series... ...	1 221 577	1 004	2 295	23 822	−1·8	4 753	80 213	—

Abstract of approximate results from remunerative works of irrigation (exclusive of tanks), in the Madras Presidency for 1872-73.

Deltaic Canals from Rivers.	District Irrigated.	Up to end of 1872–73		For year 1872–73.		Percentage of net profit.
		Total Capital Outlay.	Total Gross Income.	Interest & Maintenance.	Gross Proceeds.	
SOUTHERN INDIA.		£	£	£	£	
Godavari ...	Godavari ...	544 788	3 427 377	36 023	214 304	32·7
Kistna	Kistna ...	358 254	782 199	24 669	69 303	12·5
Pennar ...	Nellor ...	93 395	89 142	6 200	8 954	2·9
Four anicuts ...	Chinglipat ...	12 411	32 133	743	8 346	63·2
Palar	Chinglipat ...	21 493	23 233	955	5 723	
Palar	North Arcot	75 086	34 139	3 718	2 648	
	Total Palar.	96 579	57 372	4 673	8371	3·8
Poini	North Arcot	15 420	34 987	702	641	deficit
Alliabad & Cheyar ...	North Arcot	20 207	24 450	1 407	2 542	5·5
Vellar and nine others	South Arcot	52 055	395 809	4 961	33 321	53·8
Lower Kalerun	South Arcot	12 974	1 106 873	2 399	41 193	
Lower Kalerun	Tanjor ...	43 974	66 118	1 892	1 967	
Upper Kalerun	Tanjor ...	24 066	1 757 088	1 165	67 083	
	Total Kalerun	81 014	2 930 079	5 456	110 243	128·3
Nandiar ...	Trichinopoly	7 855	9 640	406	944	5·8
Four channels...	Coimbator...	22 961	24 288	3 216	2 844	deficit
Yenamakal ...	Malabar ...	4 250	5 408	206	141	deficit

N.B.—The capital outlay does not include deduction for wear and tear, nor, in some instances, the cost of the distributaries. The interest is 4 per cent on the outlay up to the beginning of 1872–73.

General Statistics of Canals in Operation in 1882–83.

Canals.	Capital Outlay.		Gross Revenue, &c., of the year 1882–83.				
	During Year.	Total.	Land Revenue.	Total.	Working Expenses.	Net Revenue.	Acres Irrigated.
NORTH-WESTERN INDIA.							
Panjab.	£	£	£	£	£	£	
Western Jamna Canal ...	55 655	884 952	5 836	121 786	47 179	74 606	374 243
Bari Doab Canal	2 552	1 552 655	27 997	137 426	52 957	84 469	353 615
Sarhind Canal	204 357	2 917 466	—	—	—	—	—
Upper Satlaj Canals ...	5	57 845	13 068	16 269	14 277	1 992	129 802
Lower Satlaj and Chinab ...	45	11 055	30 520	61 954	41 672	20 282	362 975
Indus Canals	26	70 809	15 717	22 328	22 501	deficit	190 620
Shahpur Canals	—	4 074	—	1 225	953	272	12 632
Muzaffargarh Canals ...	—	—	12 074	22 035	—	—	259 385
Sind and Northern Guzrat.							
Sind Canals	—	—	325 252	338 931	136 [illegible]68	202 563	1 673 293
Hathmathi Canal	—	—	—	820	1 003	deficit	1 958
NORTH-EASTERN INDIA.							
North-west Provinces.							
Ganges Canal	27 759	2 767 065	44 301	278 426	88 016	190 410	856 035
Lower Ganges Canal ...	98 832	2 589 624	20 783	178 616	67 181	111 435	606 025
Agra Canal	5 574	852 213	—	52 793	22 940	29 854	155 887
Eastern Jamna Canal ...	6 513	290 839	22 153	105 698	21 144	84 553	254 513
Dun Canals	25	63 739	1 595	7 166	4 744	2 421	14 968
Rohilkhand Canals... ...	2 752	168 625	5 824	12 942	11 288	1 654	7[illegible] 507?
Bengal and Bahar							
Sohan Canals	38 343	2 460 661	—	132 461	119 345	13 116	173 824
Midnapur Canal	12 247	820 467	—	32 090	24 650	7 440	101 939
Hijalli Tidal Canal... ...	—	183 808	—	4 503	4 190	314	navigation only

GENERAL STATISTICS OF CANALS IN OPERATION IN 1882–83—*continued.*

Canals.	Capital Outlay.		Gross Revenue.				
	During Year.	Total.	Land Revenue.	Total.	Working Expenses.	Net Revenue.	Acres Irrigated.
SOUTHERN INDIA.	£	£	£	£	£	£	
Orissa.							
Orissa Canals	37 248	2 067 401	—	33 832	35 528	deficit.	133 028
Bombay.							
Canals and tanks altogether	27 695	1 474 538	3 094	23 711	16 068	7 643	28 735
Madras.							
Tumbaddra Canal	1 762 505	1 762 505	—	17 602	13 973	deficit.	16 138
Godavari deltaic Canal ..	22 003	1 102 024	15 117	154 520	33 417	121 103	504 213
Kistna " " ...	20 203	633 063	12 625	86 733	28 442	58 292	261 158
Pennar { Pennar anicut ...	—	166 516	1 521	12 063	1 750	10 313	63 653
Pennar { Sangam " ...	52 585	80 207	—	—	—	—	none.
Kavari deltaic Canal ...	3 049	115 024	13 651	65 627	3 400	62 227	892 871
Srivegunthan anicut ...	1 363	131 214	225	9 126	1 825	7 301	19 546
Palar anicut...	–13 983	168 096	1 362	10 989	3 883	7 106	66 212
Pelandorai anicut	2 212	38 703	27	527	4 776	deficit.	3 386
Buckingham Canal... ...	15 745	537 450	—	—	16 699	deficit.	navigation only

BRIEF ACCOUNTS OF INDIAN CANALS.

NORTH-WESTERN INDIA.—*The Panjab.*

The Western Jamna Canal is the oldest of the perennial canals of Northern India, the most fully developed as regards its powers of irrigation, and the most remunerative. It has, however, been carried on in a most desultory manner, and even in 1872 was not complete. In 1821, the capital expended on it was £14 216, and from that time to 1833 the progress was next to nothing; in 1835, the capital account was £33 168; but in 1836, £62 225, were spent, raising it to £100 000; from that time to 1846 next to nothing was spent, the account at that date being only £119 405, according to the returns formerly given The present capital account, given in the accompanying statistics, gives different figures, owing to an entirely new arrangement; but the same rate of carrying on the works is clearly illustrated by them. In 1853–54, this canal had arrived at a very good stage of development, after more than thirty years had been passed in spending £175 000 on works. Up to 1872–73, the capital account was £311 693, but even then the canal had no permanent headworks, and the drainage works necessary for the healthy control of the irrigation were merely commenced half a century after the British first took the matter in hand.

The canal is of Mussulman origin, having been projected and carried out on a small scale under the Mughal emperors. Its head is at Tájawalla, on the west bank of the Jamna, 13 miles above Dádupur; the supply being conducted from the head along an old branch of the Jamna to Bhilpur, thence by an artificial cut into the Pattraia hill torrent, and then along the latter, down to a junction with the Sombe torrent near Dádupur, where a dam and regulating head foi the supply of the actual main canal are situated. After 102 miles of main canal it divides itself at Rer, into two main branches, the Delhi branch, 75 miles long, tailing into the Jamna near Delhi and having distributaries aggregating 100 miles in length, and the Hansi branch, which is 108 miles long to Mingnikhera, and has 141 miles of distributaries, in addition to its sub-branches. At the Joshi regulator, in the 11th mile of the Hansi branch, is the head of a sub-branch,

which loses itself in the sandy desert near Rohtak after a course of 43 miles. At the 13th mile of the Hansi branch, is the head of the Butana sub-branch, 18 miles long, down to its bifurcation into two channels, one 11 and the other 6 miles long.

At Mingnikhera, the 108th mile of the main canal, is the head of the Bahadura sub-branch, 32 miles long, and of the Darba sub-branch, which is 18 miles long down to its bifurcation at Ramsira, whence it becomes two channels, each 10 miles long.

In addition to the various branches and distributaries, there are escape cuts from the main canal amounting to 55 miles in length, and 62 miles of escapes, cuts, and drainage lines from the Delhi branch. A new branch from the 59th mile of the main canal to Bhowani was also proposed.

As regards the width of the canal, the main line varies from 360 to 120 feet, and the branches from 100 to 10; the depth is variable, the full supply depth at Dadupur being 4·3 feet, and the lowest supply about half of that; the velocity at Tajawalla is about 17, and at Dadupur with full supply 4·14 feet per second.

The tract irrigated is 120 miles by 10.

In 1837–38, a year of famine, the acreage irrigated was 306 000, the produce saved being valued at £1 462 800; and the estimated value of the irrigated crops on 351 820 acres in 1872–73, being £2 021 811. In 1846–47, 351 501, or (360 902 ?) acres were actually watered, and the following works were completed: main canal 445 miles, excluding distributaries; bridges of various sorts, 240; main headwork, 1; stop dams, 12; aqueducts, 2; weirs and falls, 9; escapes, 4; locks, 2; irrigation outlets, 672; inlets, 36; station houses, 88; besides depôts, mills, and workshops. The gross returns in 1846 amounted to 55 per cent. on the capital. The irrigating power of water on this canal is higher than that of any canal in India, having sometimes reached nearly 300 acres per cubic foot per second of supply utilized.

While the Western Jamna canal yields the most favourable results as regards its powers of irrigation, this appears rather to be due to natural conditions than to skilful management. In 1819–20, before British reconstruction, the tract irrigated, 992 square miles, yielded £200 655 in water rate, while in 1850–51, the tract irrigated was 1 015 square miles, yielding £224 177 in water rate; the increase of land revenue in each

case amounting to £41 521, and the advantages due to British military management over a quarter of a century appearing very small in this particular.

The capital account of this canal was altered in the year 1863-64, by debiting it from 1820 with a share of expenses for establishment and contingencies, thus changing the sum from £190 404 to £212 899 on 1st May, 1864; there is also some doubt about the establishment charges, whether they should be 10 or 13 per cent. on the cost of works during the whole of that period.

In 1864–65 the average monthly discharge for the year was 1 784 cubic feet per second; in the Kharif season, 1 791; and in the Rabi season, 1 777 cubic feet per second.

In this year the value of the irrigated crops being fifty times the water rent paid, it was resolved to increase the water rates, and this was actually done in 1867–68: in this latter year the rainfall was exceptionally favourable to the cultivator, the result being that only two-thirds the breadth of wheat of the preceding year was irrigated; but as there was an increase of irrigation of 7 436 acres of sugar-cane, the loss was made up.

The acreage of the principal irrigated crops on this canal for several years was as follows:—

		1860-61.	1861-62.	1862-63.	1863-64.
Sugar-cane, annual...		102	33 782	44 730	30 089
Rice ...	Kharif	44 965	58 578	57 925	47 353
Cotton ...	Kharif	43 706	33 558	25 549	45 882
Wheat ...	Rabbi ...	181 208	148 317	111 129	145 234

		1864-65.	1865-66.	1866-67.	1867-68.
Sugar-cane, annual ...		29 786	34 028	19 773	27 206
Rice ...	Kharif	57 157	51 517	62 071	39 455
Cotton ...	Kharif	77 738	62 684	104 796	98 800
Indigo ...	Kharif	1 131	1 477	1 805	1 315
Wheat ...	Rabbi ...	163 159	126 293	150 233	100 937

In 1871, Col. Crofton proposed, with an estimate of £214 267 to make a permanent head, to complete the drainage works and the distributaries from Indri to Delhi and Jhind; it had however been discovered, in 1867, that the swamps near Karnál and on the Delhi and Rohtak branches were absolutely necessary;—the

former having existed for 25 years, in consequence of the canal from Baria to Karnál consisting principally of natural channels.

The details of progress on the works between 1872 and 1882 are not forthcoming in England, but a little information about it may be gained by inference and from the capital accounts. In 1882–83 expenditure was going on, on a new main line, a new Delhi branch, a new Hánsi branch, and on the Okla navigation channel, as well as on new distributaries and drainage cuts. It appears that the permanent headworks have been completed. The existing length of main Canal open during 1878 to 1882 was 463 miles.

The acreage of the principal irrigated crops was thus:—

	1878–79	1879–80	1880–81	1881–82	1882–83
Sugar Cane	44 006	46 973	23 846	36 269	47 247
Rice	48 383	44 075	48 372	43 376	44 960
Cotton	76 286	63 201	44 213	60 485	52 461
Wheat	140 374	103 470	93 644	98 335	145 020

The estimated value of produce grown in 1882-83 under irrigation is £1 138 566.

The present state of this canal as regards financial condition and irrigation, is shown in the tabular statistics.

The Western Jamna Canal.—Abstract of Financial Statistics.

Official year.	Capital Outlay.			Working Expenses.	Direct Revenue.	Indirect Revenue.	Total Yearly Return.	Percentage of net Revenue on Capital.
	Original Works.	Establishment & other charges.	Total to end of year.					
	£	£	£	£	£	£	£	
to 1821	19 443	—	19 443	532	1 136	—	1 136	—
1821–22	—	—	—	2 568	111	—	111	—
1822–23	—	—	—	3 692	−1 065	—	−1 065	−5
1823–24	—	—	—	5 056	− 514	—	− 514	−2
1824–25	—	—	—	5 756	−2 532	12 000	9 468	49
1825–26	414	41	21 894	6 361	− 945	12 000	11 055	57
1826–27	1 814	181	19 898	7 090	−2 875	12 000	9 125	47
1827–28	—	—	—	7 862	−2 583	12 000	9 417	47
1828–29	—	—	—	8 388	− 556	12 000	11 444	52
1829–30	494	49	22 438	8 479	− 219	12 000	11 781	54
1830–31	—	—	—	9 337	− 733	12 000	11 266	50
1831–32	—	—	—	10 206	−2 118	12 000	9 882	44
1832–33	—	—	—	10 797	−1 186	12 000	10 814	48
1833–34	7 201	720	30 359	9 982	7 701	12 000	19 701	88
1834–35	9 028	903	40 290	10 874	3 652	12 000	15 652	52
1835–36	62 222	6222	108 734	4 755	9 759	12 000	21 759	54
1836–37	338	34	109 106	9 439	9 642	12 000	21 642	20
1837–38	3 174	317	112 598	10 170	19 797	12 000	31 797	29
1838–39	4 604	460	117 663	8 227	13 913	12 000	25 913	23
1839–40	626	63	118 351	9 314	16 568	12 000	28 568	24
1840–41	3 118	312	121 781	9 224	19 634	12 000	31 634	27
1841–42	1 212	121	123 114	9 520	19 937	12 000	31 937	26
1842–43	2 512	251	125 877	10 847	20 279	37 256	57 535	47
1843–44	841	84	126 802	10 314	18 785	37 256	56 041	45
1844–45	264	26	127 092	16 927	9 104	37 256	46 361	37
1845–46	1 718	172	128 982	14 161	15 727	37 256	52 983	42
1846–47	5 677	568	135 227	13 196	17 092	37 256	54 348	42

The Western Jamna Canal.—Abstract of Financial Statistics.

Official year.	Capital Outlay. Original Works.	Capital Outlay. Establishment & other charges.	Capital Outlay. Total to end of year.	Working Expenses.	Direct Revenue.	Total yearly Return.	Percentage on net Revenue on Capital.	Acreage irrigated.
	£	£	£	£	£	£		
1847–48	555	55	135 838	10 539	18 529	55 786	41	
1848–49	6 050	605	142 493	12 468	18 491	55 747	41	
1849–50	2 087	209	144 788	14 117	17 355	54 611	38	
1850–51	342	34	145 164	13 793	16 732	53 988	37	
1851–52	11 248	1 125	157 537	12 548	19 855	57 111	39	
1852–53	7 550	755	165 842	15 008	17 547	54 803	35	
1853–54	6 871	687	173 400	12 603	21 928	59 185	38	
1854–55	1 951	195	175 547	10 297	18 983	56 239	32	
1855–56	984	127	176 657	12 424	21 871	59 127	34	
1856–57	1 956	261	178 874	16 938	9 386	46 642	26	
1857–58	491	81	179 446	10 664	12 754	50 011	28	
1858–59	1 838	261	181 545	16 313	16 632	53 888	30	
1859–60	2 222	330	184 096	20 317	16 316	53 573	30	
1860–61	3 721	493	188 310	21 865	24 470	61 726	33	454 292
1861–62	8 906	1 185	198 401	22 250	18 147	55 404	29	372 680
1862–63	4 096	1 449	203 945	17 426	17 586	54 843	28	303 361
1863–64	6 845	4 618	215 408	16 408	23 297	60 553	30	351 537
1864–65	10 019	476	225 904	21 179	– 5 710	31 547	15	434 964
1865–66	903	859	227 666	20 285	28 477	65 733	20	397 963
1866–67	446	304	228 417	23 150	34 229	71 485	31	447 171
1867–68	1 795	364	230 577	28 711	66 313	103 569	45	331 037
1868–69	10 716	5 696	246 989	24 102	39 574	76 830	33	486 878
1869–70	7 939	7 955	262 884	38 979	74 405	111 611	45	496 542
1870–71	4 816	11 474	279 173	33 873	116 884	154 140	59	462 707
1871–72	5 780	13 084	298 036	37 645	6 711	108 907	39	444 385
1872–73	3 454	9 895	311 693	40 118	62 182	99 438	33	351 821

The Western Jamna Canal.—Revenue Account in Pounds Sterling (Based on Assessments).

Official Year.	Capital Outlay.		Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Revenue.	Interest.	Net Profit.
	During year.	Total.						
	£	£	£	£	£	£	£	£
1868–69	16 412	246 989	24 102	125 803	37 256	138 957	—	—
1869–70	12 755	259 744	38 979	126 426	37 256	124 703	—	—
1870–71	16 441	276 185	36 213	120 285	37 256	121 328	—	—
1871–72	16 807	*292 992	40 687	113 096	37 256	109 665	—	—
1872–73	13 656	311 693	40 118	95 362	37 256	92 500	—	—
1873–74	22 523	334 216	37 298	85 190	37 256	85 148	—	—
1874–75	47 934	381 150	33 874	101 696	37 256	105 078	—	—
1875–76	51 613	432 763	37 516	82 138	40 128	84 750	—	—
1876–77	55 618	488 380	38 937	97 115	38 592	96 770	—	—
1877–78	87 541	575 921	41 873	124 798	37 376	120 301	—	—
1878–79	90 861	656 782	41 544	† 105 865	38 348	102 670	27 990	74 680
1879–80	43 351	700 133	47 563	† 103 785	27 584	83 805	30 213	53 592
1880–81	83 399	783 532	40 825	† 92 739	10 228	62 142	32 255	29 886
1881–82	45 765	829 297	43 116	† 109 400	5 044	71 328	30 538	40 790
1882–83	55 655	884 952	47 179	† 136 442	5 836	95 099	32 497	62 602

* £298 037 in another account. † The revenue 1878 to 1883 is variously given.

The Western Jamna Canal.—Statistics of Irrigation.

Year.	Average Supply admitted.	Average Supply utilized.	Acreage Irrigated.			Length of Distributaries	Rainfall of the Year.
			Kharif.	Rabbi.	Total.		
	C. ft. p. sec.	C. ft. p. sec.				Miles	Feet.
1863–64	1 254	—	—	—	351 537		
1864–65	1 800	1 784	197 673	237 291	434 964	The distributaries chiefly belong to the landholders.	
1865–66	1 615	1 442	196 271	201 692	397 963		0·6 to 3·1
1866–67	1 833	1 790	211 103	236 068	447 171		1·9 to 5·7
1867–68	1 875	1 499	186 887	144 150	331 037		0·8 to 2·6
1868–69	2 277	—	198 670	288 208	486 878		0·8 to 2·6
1869–70	2 372	—	234 465	262 078	496 542		0·5 to 2·6
1870–71	2 067	1 797	218 535	244 172	462 707		1·2 to 4·0
1871–72	2 147	1 928	187 647	256 738	444 385		0·9 to 5·9
1872–73	2 125	1 802	202 370	149 450	351 820		1·7 to 3·8

The area of double cropped land is about 13 per cent. of the to'al acreage in 1872. The Irrigating capability varied from 430 500 acres in 1864 to 536 580 in 1871.

Mileage of canal open from 1860 to 1873: main canal, 102; branches, 313

Statement of Water utilized on the Western Jamna Canal in 1872–73.

Month.	Supply at head.	Dis-charged from escapes.	Utilized.	Month.	Supply at head.	Dis-charged from escapes.	Utilized.
Kharif.	Cub. ft. per sec.	Cub. ft. per sec.	Cub. ft. per sec.	*Rabbi.*	Cub. ft. per sec.	Cub. ft. per sec.	Cub. ft. per sec.
1872.				1872.			
April ...	2 359	234	2 125	October ...	2 413	353	2 060
May ...	2 523	555	1 968	November .	2 540	374	2 166
June ...	2 446	288	2 158	December .	1 941	396	1 545
				1873.			
July ...	2 319	229	2 090	January ...	1 242	341	901
August ...	2 142	562	1 580	February ...	1 872	249	1 623
September	1 620	143	1 477	March ...	2 084	152	1 932
Average	2 234	335	1 899	Average	2 015	311	1 704
				Average of year	2 125	343	1 802

The Western Jamna Canal.—Supply of Water and Irrigation (Later Returns).

Year.	Average Supply.				Irrigation.				Rainfall of the year.	Distributaries open.
	Kharif.		Rabbi.							
	Admitted.	Utilized.	Admitted.	Utilized.	Kharif.	Rabbi.	Total.	Double cropped land.		
	c.f.p.s.	c.f.p.s.	c.f.p.s.	c.f.p.s.	Acres.	Acres.	Acres.	Per cent. †	Feet.	Miles.
1868–69	—	—	—	—	198 670	288 208	486 878	—	0·7 to 2·6	under private owners.
1869–70	—	—	—	—	234 465	262 078	496 542	—	0·5 to 2·6	
1870–71	1 981	1 697	2 154	1 907	218 535	244 172	462 707	12·7	1·2 to 4·0	
1871–72	1 971	1 665	2 324	2 002	187 647	256 738	444 385	13·6	0·9 to 5·9	
1872–73	2 234	1 899	2 125	1 802	202 370	149 450	351 820	11·2	1·7 to 3·8	
1873–74	2 035	1 747	2 287	1 762	171 630	140 117	311 747	9·9	1·0 to 4·2	
1874–75	2 095	1 841	2 437	1 790	160 118	222 729	382 847	13·6	0·8 to 6·5	
1875–76	2 511	2 125	1 911	1 262	188 189	121 406	309 595	10·3	1·9 to 4·4	
1876–77	2 204	2 009	2 070	1 846	175 729	190 753	366 482	10·7	0·3 to 4·3	
1877–78	2 579	2 505	1 930	1 913	215 135	292 839	507 974	16·8	1·1 to 2·1	
1878–79	2 026	1 976	2 152	2 124	204 388	194 072	398 460	14·3	1·7 to 2·8	625
1879–80	2 188	1 955	2 216	1 878	174 172	136 514	310 686	12·3	0·9 to 3·0	625
1880–81	2 318	2 016	1 924	1 418	144 668	120 883	265 551	6·8	0·9 to 3·5	625
1881–82	2 481	2 050	2 018	1 653	167 721	132 824	300 545	6·5	0·7 to 3·6	635
1882–83	2 593	2 333	1 994	1 788	172 753	201 490	374 243	12·2	1·1 to 4·7	635

The official Kharif season lasts from 1st April to 30th September. † Percentage on the Total.

The Western Jamna Canal.—Capital Account to the end of 1872-73.

Detail.	Previous.	In 1872-73.	Total.
	£	£	£
A. *Temporary Head Works* (to main-supply)	—	78	78
B. *Cost of Land*	3 316	29	3 345
C. *Masonry Works.*—1. Main Canal and branches	—	—	—
a. Dams, and regulating works ...	2 487	1 017	3 504
b. Falls and weirs	9 050	336	9 387
c. Aqueducts	248	—	248
d. Escapes	563	—	563
4 Supply of tanks	1 555	—	1 555
5. Road bridges	1 679	—	1 679
8. Buildings	201	330	350
D. *Earthwork.*—1. Main Canal and branches	18 542	948	19 490
3. Drainage works	1 714	—	1 714
E. *Miscellaneous*	1 312	138	1 450
Total Main Canal, and branches ...	40 486	2 877	43 364
Distributing Channels.			
C. *Masonry works.*—*d.* Irrigation Outlets	—	576	576
Expenditure on general works up to 1863-64	194 341	—	194 341
Total on Works ...	234 827	3 453	238 281
Direction	—	908	—
Executive	—	4 430	—
Survey	—	5 417	—
Total on Establishment ...	56 645	10 755	67 400
Total on Tools and Plant ...	1 407	19	1 426
	292 879	14 228	307 107
Add or deduct fluctuations of suspense balance: for stock, sales, and advances ... ... Total	5 158	−572	4 586
Total Capital Outlay ... £	298 037	13 656	311 693

The Western Jamna Canal.—Capital Account in 1883.

Detail.	Previous.	In 1882–83.	Total.
	£	£	£
(1) *Headworks—*			
Works, land and buildings ...	44 866	...	44 866
(2) *Canal and Branches—*			
Land	16 268	211	16 479
Regulators	15 686	6	15 692
Falls and Weirs	24 241	417	24 658
Cross-drainage works	10 290	737	11 027
Bridges	44 938	4 755	49 693
Escapes	21 918	321	22 239
Navigation works	68 730	23 392	92 121
Mills and Buildings	7 699	4	7 703
Earthwork	96 289	1 077	97 366
Plantations	413	52	465
Miscellaneous, preliminary, and maintenance	8 840	1 901	10 743
(3) *Distributaries—*			
Land	4 116	368	4 484
Works	13 233	5 339	18 572
Earthwork	14 467	4 062	18 529
Miscellaneous, preliminary, and maintenance	2 639	775	3 414
(4) *Drainage and Protective Works—*			
Land	660	34	694
Works	2 329	767	3 096
Earthwork	2 636	286	2 921
Miscellaneous and preliminary ...	459	50	509
Total on Works since 1863–64	400 717	44 553	445 269
" " to end of 1863–64 ...	192 412	—	192 412
Total on Works	593 129	44 553	637 681
,, on Establishment, from beginning	170 922	11 195	182 117
,, on Tools and Plant	10 649	337	10 986
,, Suspense Account...	11 391	(−1 694)	9 698
Grand Total	786 091	54 391	840 482

The Bari Doab Canal, from the Ravi in the Panjab, is the fourth of the large perennial canals of Northern India. It was commenced in 1850, with an original estimate of £530 000, and the greater portion of the main canal and works were finished in 1869; as no account of the detail of progress is forthcoming, it will be best to describe the project as contemplated.

The canal is taken off from the left bank of the Ravi near Madhopur, and after a length of 28 miles throws out the Kasur branch at Tibari: at the 7th mile of the Kasur branch, the Subraon branch takes off; these two branches will be 90 and 67 miles long respectively, the former tailing into the Kasur nallah at Aljowan, the latter into the Tatti nallah at Subraon. The portion of the main canal from the head of the Kasur branch to that of the Lahor branch, which is situated in the 52nd mile near Aliwal, is designated the Upper main branch, and is 24 miles long. The remaining portion of the canal, from the head of the Lahor branch to the Vahn escape, into which the canal tails, is called the Lower main branch, and is 88 miles long; this passes the town of Amritsar, and discharges itself through the Vahn escape into the Ravi. The Lahor branch from Aliwal passes Lahor, and tails into the Ravi at Nizabeg, 9 miles below Lahor: its length is 59½ miles.

The section of each branch is as follows:—

	Breadth at head.		Breadth at tail.		Depths.	
	Bed.	Mean.	Bed.	Mean.	Highest.	Lowest.
Main line	112	120	112	120	4·9	2·5
Upper main branch ...	84	92	80	88	5·6	2·8
Lower main branch ...	70	77	56	63	4·6	2·3
Lahor branch... ...	50	55	38	43	3·3	1·6
Upper Kasur branch...	60	66	60	66	4·0	2·0
Lower Kasur branch...	46	51	20	25	3·0	1·5
Subraon branch ...	50	55	20	25	3·3	1·6

The highest depths given are those with the full supply of 3000 cubic feet per second, the lowest, those with the lowest recorded supply of 1 000: the mean width is that of the wetted section at full supply.

The mean velocity, with a full supply depth of 4·9 feet, is 5·3 feet per second, and that with an average depth of 4·2 feet at the canal head is 4 feet per second

The canal is capable of irrigating 654 000 acres with full supply at a duty of 218 acres per cubic foot per second.

The distributaries and escapes are as follows:—

From	Number of distributaries.	Total length. Miles.	Escapes.	Length Miles.
Main line	15	93	Malikpur ...	7
Upper main branch ...	10	75	Gulpur ...	9
Lower main branch ...	16	256	Sirkian ...	6
Lahor branch	23	291	Aliwal ...	11
Kasur branch ...	Not yet determined		Vahn ...	16
Subraon branch	Not yet determined		Nizabeg ...	$1\frac{1}{2}$

In the neighbourhood of Pathankot, there are two hill torrents, the Jennah and the Chakki, which with their branches cross the line of the canal, and had to be diverted.

In 1856 it was found that the cost of the canal would not be less than £1 350 000, and work was therefore concentrated on the first 55 miles down to the Lahor branch. In 1859 water was admitted, and it was then found that, as in the case of the Ganges canal, the declivity of bed allowed was too great, the consequence being extensive channelling out in the sandy tracts and deep holes below the falls; it was also discovered that the minimum supply of the Ravi, calculated to be 2 753, was actually only 1 414 cubic feet per second, or less than the works were designed to carry.

In 1860, a native canal, the Hasli, yielding £84 985 by direct returns, and £86 387 by enhanced land-tax, was incorporated in the account of the Bari Doab Canal, which then yielded nothing.

In 1870, or eleven years after the above-mentioned discovery, the remodelling of the canal was commenced, and the Kasur and Subraon branches proceeded with, but as an additional supply from the Beas involved fresh works, the estimate of the canal and branches rose to £2 000 000. Progress in the remodelling was going on in 1872–73, and the headworks at Madhopur were nearly completed. In 1872 the aggregate length of main canal completed was 212 out of 247 miles, and of distributaries, 692 miles. In spite, therefore, of everything to the contrary, the irrigation from this canal in 1872 brought in a gross return of £81 876, or a net return of £50 216, or nearly 4 per cent.

The acreage of the principal irrigated crops grown during four years was as follows:—

	1864-65.	1865-66.	1866-67.	1867-68.
Sugar-cane, annual ...	9 878	9 181	9 156	10 600
Rice ... } Kharif	29 212	53 564	57 615	63 661
Cotton ... } Kharif	3 881	5 236	12 511	21 101
Cereals, Rabbi ...	97 722	59 827	108 707	122 720

The estimated value of the irrigated crops grown is as follows, for several years:—In 1860-61, £256 024; in 1861-62, £307 238; in 1862-63, £192 668; in 1863-64, £241 969; and in 1872-73, £913 706.

Mileage of canal, from 1860 to 1873: main canal, 140 miles; branches, 59 miles. Full irrigating capability, 654 000 acres.

Details of the development of the works between 1872 and 1882 are not available in the official records.

It appears that the length of canal, main and branch together, was 211 miles in 1878-79, and from 1879-80 to 1882-83 it was 354 miles; proving a large increase in 1879-80.

The principal crops grown are:

	1878-79	1879-80	1880-81	1881-82	1882-83
Sugar Cane	8 746	10 718	12 397	12 707	12 245
Rice	36 719	42 772	44 594	32 582	39 783
Cotton	23 036	25 913	23 314	28 712	29 353
Wheat	171 936	197 865	219 838	178 743	156 054

The estimated value of produce grown in 1882-83 was £953 466. Details of the irrigation and the revenue from this canal are given in the tabular statistics.

Bari Doab Canal.—Abstract of Financial Statistics.

Year.	Capital Outlay.	Charges.	Direct Income.	Total Income.	Net Income.
	£	£	£	£	£
1860-61	957 441	14 797	22 687	—	—
1861-62	—	17 992	30 593	—	—
1862-63	—	27 523	32 316	—	—
1863-64	1 129 941	30 591	35 126	—	—
1864-65	1 140 822	39 813	49 066	—	—
1865-66	1 151 381	35 506	46 759	54 613	—
1866-67	—	31 710	58 475	66 328	—
1867-68	—	—	—	—	26 911

The Bari Doab Canal.—Statistics of Irrigation.

Year.	Supply admitted	Supply utilised.	Acreage Irrigated. Kharif.	Rabbi.	Total.	Length of Distributaries	Rainfall.
	C.ft.p.s.	C.ft.p.s.				Miles.	Feet.
1861–62	1 387	—	—	—	134 362	—	—
1862–63	1 450	—	59 476	66 540	126 016	409	—
1863–64	1 340	1 193	64 195	70 167	134 362	554	—
1864–65	1 228	—	66 370	126 313	192 683	581	—
1865–66	1 431	—	91 378	84 602	175 980	623	—
1866–67	1 688	—	92 699	135 753	228 452	671	—
1867–68	1 532	—	106 043	156 085	262 128	696	—
1868–69	1 899	1 649	85 519	214 315	299 834	706	0·4 to 2·7
1869–70	1 948	1 578	115 524	118 403	233 927	710	1·6 to 2·8
1870–71	2 201	2 069	88 643	190 567	279 210	710	0·7 to 4·0
1871–72	2 073	1 950	76 412	210 658	287 079	712	0·8 to 5·4
1872–73	1 838	1 208	96 718	132 078	228 796	716	1·6 to 4·4

The area of double cropped land from 1870 to 1873 was 8 per cent. of the whole acreage.

Statement of Water utilised on the Bari Doab Canal in 1872–73.

Month.	Supply at head.	Discharged from escapes.	Utilised.	Month.	Supply at head.	Discharged from escapes.	Utilised.
Kharif.	Cub. ft. per sec.	Cub. ft. per sec.	Cub. ft. per sec.	*Rabbi.*	Cub. ft. per sec.	Cub. ft. per sec.	Cub. ft. per sec.
1872.				1872.			
April ...	2 198	1 060	1 138	October ...	2 202	989	1 213
May ...	2 208	1 046	1 162	November	2 095	915	1 180
June ...	2 146	504	1 642	December	1 640	471	1 169
				1873.			
July ...	1 776	850	926	January ...	782	217	565
August ...	1 796	768	1 028	February ...	880	49	831
September	1 986	561	1 425	March ...	2 342	125	2 217
Average	2 018	798	1 220	Average	1 657	461	1 196
				Average of year	1 838	629	1 208

The Bari Doab Canal.—Supply of Water and Irrigation (Later Returns).

Year.	Supply. Kharif. Admitted.	Supply. Kharif. Utilised.	Supply. Rabbi. Admitted.	Supply. Rabbi. Utilised.	Irrigation. Kharif.	Irrigation. Rabbi.	Irrigation. Total Acre.	Irrigation. Double Cropped Land.	Rainfall of the Year.	Distributaries open.
	c.f.p.s.	c.f.p.s.	c.f.p.s.	c.f.p.s.	Acres.	Acres.		Per cent.	Feet.	Miles.
1868–69	...	...	...	...	85 519	214 315	299 835	...	0·4 to 2·7	...
1869–70	2 419	1 715	1 476	1 306	115 524	118 403	233 927	...	1·6 to 2·8	692
1870–71	2 301	1 692	2 012	1 933	88 643	190 567	279 210	6·9	0·7 to 4·0	692
1871–72	2 200	1 844	1 946	1 893	76 412	210 658	287 070	4·1	0·8 to 5·4	694
1872–73	2 018	1 220	1 838	1 208	96 718	132 078	228 796	6·6	1·6 to 4·4	702
1873–74	2 508	2 315	1 592	1 459	100 913	131 233	232 146	10·6	1·5 to 4·6	706
1874–75	2 229	2 097	2 050	1 954	87 214	192 599	279 813	11·0	0·9 to 4·2	706
1875–76	1 879	1 607	1 525	1 393	92 335	122 264	214 599	11·8	1·9 to 5·7	706
1876–77	1 748	1 500	1 342	862	75 748	126 964	202 712	13·0	1·5 to 6·8	706
1877–78	1 823	1 552	1 130	972	85 664	181 331	266 995	10·5	1·0 to 4·0	706
1878–79	2 001	1 821	1 958	1 926	116 463	211 095	327 558	10·2	1·5 to 2·6	706
1879–80	2 501	2 396	2 073	2 056	149 436	243 881	393 317	13·6	1·4 to 3·2	862
1880–81	2 759	2 695	1 950	1 919	151 104	281 976	433 080	13·1	0·9 to 3·4	862
1881–82	1 954	1 784	1 681	1 669	126 872	241 130	368 002	12·4	1·8 to 4·9	862
1882–83	2 725	2 451	1 994	1 868	146 471	207 144	353 615	14·1	1·8 to 3·5	867

The Bari Doab Canal.—Revenue Account in Pounds Sterling (Based on Assessments).

Official Year.	Capital during Year.	Outlay. Total.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Revenue.	Interest.	Net Profit.
	£	£	£	£	£	£	£	£
1868–69 ...	...	...	36 559	73 945	26 840	64 226	...	...
1869–70 ...	...	1 202 446	36 875	57 559	20 503	41 187	...	...
1870–71 ...	57 076	1 259 522	42 097	73 409	26 143	57 455	...	...
1871–72 ...	47 534	*1 307 056	37 311	71 028	25 041	58 708	...	...
1872–73 ...	25 828	1 344 957	31 570	63 469	18 318	50 216	...	...
1873–74 ...	30 121	1 375 078	34 609	66 511	18 845	50 747	...	...
1874–75 ...	37 701	1 412 779	33 746	75 977	21 579	63 810	...	...
1875–76 ...	38 833	1 451 612	48 094	62 350	15 760	30 016	...	...
1876–77 ...	18 115	1 469 727	55 365	59 853	15 386	19 874	...	...
1877–78 ...	13 923	1 483 650	52 399	68 963	20 010	36 575	66 498	loss
1878–79 ...	11 794	1 495 444	51 436	89 438	25 450	†63 453	67 078	loss
1879–80 ...	734	1 496 178	50 229	104 580	33 965	†88 317	67 265	21 052
1880–81 ...	60 471	1 556 649	42 272	119 177	32 729	†109 634	67 285	42 349
1881–82 ...	(−14 413)	1 555 207	51 057	103 733	31 626	†84 303	59 789	24 514
1882–83 ...	(−2 552)	1 552 655	52 957	101 346	29 879	†77 148	59 708	17 440

* £1 319 129 in another account. † The revenue 1878–83 is variously given.

The Bari Doab Canal.—Capital Account to the end of 1872-3.

Detail.	Previous.	In 1872-73.	Total.
Works.	£	£	£
B. *Cost of Land*	7 333	—	7 333
C. *Masonry works.*—1. Main Canal and branches—			
a. Dams and Regulating works ...	75 798	155	75 949
b. Falls and Weirs...	137 242	6 675	143 917
c. Aqueducts	17 883	—	17 883
d. Escapes	15 474	—	15 474
3. Drainage works...	2 473	—	2 473
5. Road bridges	103 601	94	103 694
6. Navigation works	18 949	—	18 949
7. Mills	1 267	—	1 267
8. Buildings	22 014	536	22 550
D. *Earthwork*—			
1. Main Canal and branches ...	432 709	3 893	436 601
3. Drainage works...	7 101	—	7 101
5. Navigation Channels	8 193	—	8 193
E. *Miscellaneous*	65 736	46	65 782
F. *Plantations*	5 507	—	5 507
Total Main Canal and branches	921 276	11 398	932 674
Distributing Channels.			
B. *Cost of Land*	3 567	—	3 567
C. *Masonry works.*—*a.* Head sluices and Regulating works	5 343	113	5 456
b. Falls and Weirs...	11 194	—	11 194
c. Aqueducts	14 032	—	14 032
d. Irrigation outlets	6 113	815	6 928
D. Earthwork	73 967	243	74 210
Total on Works ...	1 035 492	12 569	1 048 061
Establishment, General.			
Direction	—	1 761	—
Executive	—	11 354	—
Medical	—	51	—
Total Establishment ...	202 715	13 166	215 881
Tools and Plant	46 853	70	46 923
Profit and Loss	4 477	—	4 477
Fluctuations of Suspense Balance	29 592	23	29 615
Total Capital Outlay ...	1 319 129	25 828	1 344 957

The Bari Doab Canal.—Capital Account in 1883.

Detail.	Previous.	In 1882–83.	Total.
	£	£	£
(1) *Headworks*—Works and Buildings	75 915	—	75 915
(2) *Canal and Branches*—			
Land	12 013	—	12 013
Regulators	33 404	—	33 404
Falls and Weirs	150 389	514	150 904
River and Torrent works ...	54 000	—	54 000
Other Cross drainage	11 780	—	11 780
Bridges	81 944	—	81 944
Escapes	63 873	—	63 873
Navigation works	47 859	—	47 859
Mills and Buildings	37 187	(– 250)	36 937
Earthwork	362 989	—	362 989
Plantations	6 548	117	6 665
Preliminary, misc. and maintenance	43 153	—	43 153
(3) *Distributaries*—			
Land	5 215	438	5 653
Works	64 097	—	64 097
Earthwork	85 416	—	85 416
Preliminary, misc. and maintenance	15 177	407	15 584
Special channels	11 193	—	11 193
(4) *Drainage and Protective Works*—			
Land and Works	2 691	—	2 691
Earthwork	8 351	—	8 351
Total—on Works	1 173 192	1 226	1 174 418
,, on Establishment	263 866	135	264 002
,, on Tools and Plant	48 045	—	48 045
,, Suspense Account	10 319	(– 3 907)	6 413
Grand Total	1 495 422	(– 2 545)	1 492 877

The Sarhind Canal, from the Satlaj in the Panjab, is a perennial canal now under construction. It was originally projected by Sir William Baker, in 1840, the detailed project was forwarded by Colonel Crofton, in 1862, and estimates for the works to the value of £2 980 427 were sanctioned early in 1872.

The headworks are at Rupar, a town at the foot of the hills. At the 38th mile (these are canal miles of 5 000 feet) the main canal crosses the Grand Trunk Road, and the railway from Ludhiana to Ambala. At the 41st mile the main canal ends, and the feeder line and the combined British branches take off. The length of the combined British branches is to be 3 miles, after which they will divide into the Ubohar branch, 125 miles long, and the Bhatinda branch, 100 miles long; the former of these will be navigable up to its 51st mile, whence the Satlaj navigation channel will take off, and after a course of 45 miles tail into the Satlaj. The feeder line, which is a continuation of the main line, will be divided into three sections by the heads of the Kotla, Gaggar, and Choa branches of the canal, belonging to native states, which take off the right side of the line; the lengths of the three sections of the feeder line being 14, 16, and 9 miles respectively, while that of the three branches are to be 90, 56, and 25 miles. The end of the feeder line is to be the point of junction of the heads of the Choa branch and the Patiala navigation branch. The latter will be 6 miles long, and will tail into the Patiala nallah near Patiala. The Choa branch will for the present tail into the Gaggar river, although it was proposed to connect it with the Western Jamna Canal by a navigation cut 55 miles long, joining it at Indri.

This canal being partly for the benefit of native territory, one-third of its cost will be borne by three native states.

Up to the end of 1870–71, the capital account amounted to £185 667, of which half was expended in works; to the end of 1871–72, £415 186, of which £276 260, was on works; to the end of 1872–73, £601 315, of which £425 078 was expended in works, independently of establishment; of the latter sum, £240 613 was expended on about 200 million cubic feet of earthwork, and £107 010 on head and regulating works.

This canal with its branches will be 554 miles long, and will irrigate 783 000 acres in a most neglected tract of country.

The Sarhind Canal was formally opened on November 24,

1882; a small amount of irrigation was effected in that year; the distributaries and unfinished branches were also in progress of construction.

Native states contributed £1 041 751 to the expense of this work.

The Sarhind Canal.—Capital Account in 1883.

Detail.	Previous.	In 1882–1883.	Total.
(1) *Headworks—*	£	£	£
Land and Works	83 390	4 033	87 423
Buildings	10 470	258	10 728
Miscellaneous and Maintenance	3 428	7 626	11 054
(2) *Canals and Branches—*			
Land	63 292	1 371	64 664
Regulators	59 025	3 765	62 789
Falls and Weirs	82 836	13 297	96 133
Cross-drainage works	230 355	(−3 797)	226 561
Bridges	75 552	4 436	79 989
Escapes	15 753	2 966	18 719
Navigation works	192 110	8 417	200 527
Buildings	35 915	2 917	38 831
Earthwork	678 003	60 086	738 089
Plantations	2 823	1 257	4 080
Preliminary, misc. and maintenance	31 025	8 948	39 973
(3) *Distributaries—*			
Preliminary	1 877	529	2 406
Land	221	44	265
Works	11 049	13 144	24 193
Earthwork	—	10 391	10 391
(4) *Drainage and Protective Works—*			
Land	6 591	1 461	8 052
Earthwork	84 707	10 664	95 371
Preliminary and Maintenance ...	309	2 156	2 465
Total—on Works	1 668 730	153 974	1 822 704
„ on Establishment	553 691	38 580	592 271
„ on Tools and Plant	362 586	6 400	368 986
„ Suspense Accounts	48 385	3 637	52 023
Grand Total	2 633 392	202 591	2 835 982

Inundation Canals of the Panjab.

Lower Satlaj and Chenab Canals.—The canals from the Lower Satlaj are 19 in number, and have an aggregate length of 418 miles; those from the Chenab are 13 in number, and have an aggregate length of 222 miles; the whole of these, excepting 19 miles, were constructed and in working order at the time of the British annexation; the breadth of these canals varies from 5 to 36 feet, and their depth of water from 3 to 11 feet; they have no distributaries, irrigation being supplied direct from them by means of private water-courses.

The day's labour of silt clearance performed by *chers* (labourers) is estimated at 90 to 130 cubic feet daily, with a lift of 10 to 18 feet, and a lead of 40 to 100 feet. The clearing begins in the middle of December, and is completely finished in April, but on some lands not until the middle of May. Water is admitted into the canals when they are cleared, and ceases to flow at the end of September, or the beginning of October; but in some channels it flows until the middle of November.

Sometimes the river does not attain its ordinary high level, and this may cause the ruin of the irrigated indigo crops. If the river rises late, less cotton crop is sown, and when it subsides early less wheat crop is grown. The effects on the Upper Satlaj Canals are nearly the same.

Lower Satlaj and Chenab Canals.—Irrigation and Revenue.

Year.	Irrigation.	Number of *chers* (labourers).	Cost of Clearance and Repairs.	Working Expenses	Capital Account.	Gross Total Income.	Annual Rainfall
	Acres.		£	£	£	£	Feet.
1868–69	199 463	—	—	—	—	—	—
1869–70	243 094	410 776	—	—	10 083	—	0·51 to 1·25
1870–71	202 036	451 078	22 975	18 819	11 298	36 756	0·15 to 0·61
1871–72	188 465	—	—	14 414	11 886	31 951	—
1872–73	242 504	—	—	16 362	10 520	34 272	—
1873–74	197 064	—	—	16 399	10 471	33 477	—
1874–75	273 688	—	—	15 627	10 756	32 092	—
1875–76	277 883	—	—	16 369	10 791	33 470	—
1876–77	285 645	—	—	15 564	10 764	32 576	—
1877–78	284 680	—	—	16 962	10 808	32 059	—

Lower Satlaj and Chenab Canals—continued.

Year.	Irrigation.	Number of *chers* (labourers.)	Cost of Clearance and Repairs.	Working Expenses	Capital Account.	Gross Total Income.	Annual Rainfall
	Acres.		£	£	£	£	Feet.
1878–79	331 639	487 518	—	—	10 955	—	0·47 to 0·89
1879–80	268 040	461 092	—	21 510	11 022	40 278	0·13 to 0·46
1880–81	299 284	477 710	—	—	—	—	0·21 to 0·54
1881–82	346 278	418 266	—	35 127	11 010	59 360	0·16 to 0·67
1882–83	362 975	452 005	—	41 672	11 055	61 954	0·35 to 0·93

The Upper Satlaj Canals are four in number:—

Canal.	Length.	Breadth.	Depth.	Distributaries.
The Khanwah	81 miles	60 feet	6 feet	47 miles.
The Upper Sohag ...	57 „	40 „	4 „	
The Katora	66 „	33½ „	3·5 „	
The Lower Sohag ...	20 „	20 „	3 „	

The first was constructed, for a length of 63 miles, during the reign of Akbar: it was reopened in 1843, and extended by the British Government for 18 miles from Dewalpur southward; 25 miles of distributaries were also constructed at that time. The second was constructed by the British Government, and opened in 1855; it has two distributaries belonging to the Government, 12 miles in aggregate length, and two to landholders of 16 miles, or 28 miles in all; a new head was completed in 1871 to serve as an alternative entrance to this canal, for occasions when the river sets in on the old head. The Katora was constructed by the British Government, and opened in 1870. The Lower Sohag was constructed by a landowner shortly after the British annexation. There is also another canal, called the Nikki, about which particulars are wanting.

The following are later data about these canals:—

Canal.	Length.	Months open annually.	Discharging c.f.p.s.	Water wheels.	Miles of distributaries.
The Khanwah	70 miles	7 ...	800 ...	203	35
The Upper Sohag	77 „	5 ...	350 ...	138	12
The Katora	66 „	4 ...	230 ...	160	
The Lower Sohag	20 „	4 ...	105 ...	60	

Under ordinary conditions of average rainfall, and an average

period of supply of six months, the irrigation duty effected is about 80 acres per cubic foot per second of supply.

The land irrigated is mostly in the Lahor district. The value of the irrigated crops of the year 1869-70 was estimated at £157 926.

Upper Satlaj Canals.—Irrigation and Revenue.

Year.	Irrigation.	Number of *chers* (labourers).	Cost [illegible] Cle[illegible]ance [illegible] Repai[illegible]	[illegible]rking [illegible]penses	Capital Account.	Gross Total Income.	Annual Rainfall
	Acres.		£	£	£	£	Feet.
1868-69	78 063	—	—	—	—	—	0·83
1869-70	148 924	—	—	8 483	51 080 ?	—	0·93
1870-71	77 070	—	8 288	10 422	56 454	5 619	0·35
1871-72	87 043	—	—	15 255	56 454 ?	6 383	—
1872-73	135 349	—	—	12 496	44 292	9 498	—
1873-74	65 233	—	—	11 703	44 271	14 493	—
1874-75	84 120	—	—	11 064	49 132	10 959	—
1875-76	138 937	—	—	11 307	51 599	9 010	—
1876-77	74 243	—	—	7 836	56 767	8 739	—
1877-78	81 185	—	—	6 551	56 813	10 721	—
1878-79	132 961	—		10 363	56 882	18 888	0·44 to 1·26
1879-80	99 477	—		11 929	56 859	12 393	0·07 to 1·24
1880-81	154 536	—	—	9 043	57 850	12 933	0·45 to 1·02
1881-82	179 578	—	—	9 080	57 840	22 033	1·16 to 1·38
1882-83	129 802	—	—	14 277	57 845	14 359	—

The Indus Canals are 13 in number, and have an aggregate length of 577 miles, varying from 9 to 97 miles in length; they are all drawn from the right bank of the Indus in the Dera-Ghazi Khan district, at the south-western corner of the Panjab frontier: their breadth varies from 11 to 60 feet, and their depth of water from 3 to 6·5 feet; they have branches, but none of them have separate distributary channels. They were all, except one of 67 miles, the Dhundi, running at the date of British annexation; but branches to the aggregate length of 32 miles have been added since, half the expense being borne by the British Government, and half by the proprietors of the estates benefited. In addition to the above, two canals, the Fazilwah

and the Masuwah, have been constructed and maintained by private enterprise.

The Shorea is fed from the Manka, and the Dhundi from the Nur. The Samundri and the Dhingana have only one head in the river, and are hence treated as one canal.

In 1879, the Nur and Dhundi Canals were purchased for £11 134, and annexed to the rest under official control.

These canals were, in 1870, thirteen in number.

Canals.	Length in Miles.	Discharge in cub. ft. per sec.	Number of Villages Irrigated.
1. The Manka	97	800	19
2. Kot Daud	9	79	10
3. Shorea	46	263	43
4. Kasturi	23	271	23
5. Samundri and Dhingana...	75	620	51
6. Chibri	28	217	20
7. Sahiba	48	280	46
8. Gamunwala	14	150	5
9. Nur	24	241	16
10. Sohan	60	446	6
11. Dhundi	67	324	19
12. Kutab	41	182	14
13. Kadra	60	234	37
	592	4 107	309

In addition to the canals, there is a number of embankments, of an aggregate length of 38 miles, in the neighbourhood of Dera-Ghazi Khan, that were constructed in 1854 and 1863 for the purpose of shutting out overflows in the rainy season, which used annually to devastate large tracts of country, and necessitate remissions of Government land-revenue.

The Dams, or embankments are :—

1. The Great Inundation Dam.
2. Kaim Ki Basti.
3. Kuliwala.
4. Bahar Shah.
5. Pitaffi.
6. Shah Jamál.

The whole of the Indus Canals were much damaged in 1878, causing much loss in the two years following.

Indus Canals (Panjab).—Irrigation and Revenue.

Year.	Irrigation.	Cost of Clearance and Repairs.	Working Expenses.	Capital Account.	Gross Total Income.	Annual Rainfall.
	Acres.	£	£	£	£	Feet.
1868–69	107 160	8 549	—	—	—	0·05 to 0·75
1869–70	129 177	6 399	12 543	36 725	—	0·33 to 0·90
1870–71	174 342	7 073	11 854	38 514	16 680	0·12 to 0·54
1871–72	144 334	—	15 783	42 057	13 962	—
1872–73	180 137	—	18 046	43 736	15 960	—
1873–74	163 020	4 663	15 806	43 761	22 023	—
1874–75	171 822	5 473	19 174	46 863	12 743	—
1875–76	144 960	5 044	19 001	57 521	22 141	—
1876–77	166 574	4 968	21 396	61 065	18 490	0·11 to 0·61
1877–78	175 960	5 420	25 337	57 748	18 389	0·19 to 0·58
1878–79	208 888	5 750	—	58 096	—	0·40 to 1·07
1879–80	144 337	5 274	30 387	69 192	18 670	0·04 to 0·33
1880–81	164 385	—	—	—	—	0·14 to 0·46
1881–82	190 802	—	18 602	70 782	21 568	0·16 to 0·59
1882–83	190 620	—	22 501	70 809	22 252	0·42 to 1·04

Note.—The cost of clearance is included in the working expenses.

The Jhelam Canals.—There are 18 inundation canals from this river in the Shahpur district; they were purchased from local funds in 1870. The dimensions of two of them are as follow:—

		Length.	Mean breadth.	Average depth.
Shahpur Canal	...	17 miles	18 feet	6 feet.
Sahiwal Canal	...	19 "	10 "	4·5 "

The returns from these are obtained by a rate of £1·6 annually on each water-wheel (jhallar), which irrigates about 5 acres; also by taking and selling one-fourth the produce grown on irrigated private lands, or one-half of that grown on Government waste land leased to cultivators.

Until 1881 the management of these three canals remained in the hands of the magisterial tax collectors.

Jhelam Canals (Shahpur and Sahiwal only) until 1877–78.

Year.	Irrigation	Cost of Clearance and Repairs.	Working Expenses.	Capital Account.	Gross Total Income.	Annual Rainfall.
	Acres.	£	£	£	£	Feet.
1868–69	—	—	—	—	—	—
1869–70	—	—	—	—	—	—
1870–71	2 460	—	414	2 060	501	—
1871–72	4 113	—	418	2 122	483	—
1872–73	4 445	—	434	2 122	698	—
1873–74	4 080	—	419	2 122	534	—
1874–75	6 355	—	369	2 122	790	—
1875–76	4 041	—	521	2 122	625	—
1876–77	9 123	—	578	2 281	1 742	—
1877–78	5 588	—	600	3 758	1 198	—
1878–79	9 189	—	—	4 046	1 554	—
1879–80	4 487	—	926	4 046	1 009	—
1880–81	9 135	—	—	4 074	1 844	—
1881–82	11 523	—	966	4 074	2 180	—
1882–83	12 632	—	953	4 074	2 681	—

NOTE.—Irrigation from the Macnabb Canal commenced in 1878–79.

The Inundation Canals of the Panjab.

Capital Account to end of 1882–83.

1. Lower Satlaj and Chenab inundation canals (complete)—		£
Main canal and branches		9 610
2. Upper Satlaj inundation canals (complete)—	£	
Main canal and branches	34 690	44 523
Distributaries	9 833	
3. Indus inundation canals (complete)—		
Main canal and branches	31 896	66 365
Drainage and protective works	34 469	
4. Shahpur Canal from the Jhelam since 1870—		
Main canal and branches (complete)—		3 764

Panjab Inundation Canals.—Revenue and Irrigation in 1872–73.

	Capital Outlay up to end of 1872-73.	Returns of 1872-73. Direct.	Indirect.	Working Expenses	Acreage irrigated in 1872-73. Kharif.	Rabbi.	Total.
	£	£	£	£			
Lower Sutlaj and Chenab	10 520	12 938	21 330	16 362	149 143	93 361	242 504
Upper Satlaj ...	44 292	6 459	2 791	15 621	74 914	60 446	135 360
Indus	43 736	?	8 094	18 046	132 818	47 319	180 137
(average) ...	—	2 700	—	—	—	—	—
Jhelam ...	2 122	710	–	434	unknown	4 445	10 513

Of the acreage irrigated by the Lower Satlaj and Chenab Canals, 20 per cent. was lift irrigation. The mean discharge of the Upper Satlaj Canals was 1 742, and that of the Indus Canals was 4 107 cubic feet per second in 1872. The Jhelam Canals were under the management of the collectors.

The returns from 1872 to 1882 are before given in detail

Minor Canals of the Panjab.

List of Minor Canals in Progress (commenced) in 1882–83.

1. Chenab Canal.
2. Lower Sohag and Para.
3. Sidhnai Canal.
4. Swat River Canal.

The Canals of Bhawulpur.—According to the account of Mr. Minchin in 1868, the canals are all inundation channels irrigating from April to September.

The total acreage under irrigation in 1868 was—by canals, 343 702 acres, besides 260 377 acres irrigated by direct flood, and 107 930 acres irrigated from 9 708 wells and 1 549 jhallars. There were 92 canals, mostly 13 feet wide by 6 feet deep; having a combined length of 761 miles and supplying 2 090 villages. In the Kharif the crops chiefly grown are rice and jowar; in the Rabbi, wheat, barley, and grain.

The names of the chief canals are the Husen Wah, Khan Wah, Diwan Wah, and Sirdar Wah.

In 1867 a new entrance was cut from the river to the Khan Wah, 6 miles long, 100 feet wide, and 9 feet deep, effected in six weeks by Murad Shah. An old river bed in Kardaree, by

making a cut from the river to it 15 miles long, was also transformed into a canal.

There are not any accounts kept of these canals, which are probably in the charge of the tax collectors.

Abdulrahman Khan's Canal.—There is no historical information forthcoming about this canal; which was probably purchased. Its main canal and branches are complete; but the work was under suspension in 1882.

Muzaffargarh Canals.—These are a series of inundation canals near Muzaffargarh in the lower part of the Sind Sagar Duab; most of them take their supply from the Indus, and 94 per cent. of the irrigation is by natural flow. Some of the canals draw their supplies from the Chenab. The annual rainfall of this district varies from 0·20 to 1·00 foot yearly. The annual clearance involves the attendance and work of about 400 000 men (chers, labourers). The total areas irrigated during three years were thus :—

	Acres.	Total Revenue. £	Working Expenses. £	Net Revenue. £	Total Value of Crops. £
1880–81	239 906	...	...	...	...
1881–82	248 593	...	...	17 897	436 733
1882–83.	259 385	33 675	15 366	18 310	511 416

Sidhnai Canals.—This inundation canal, in progress of construction, has its headworks at Theyráj on the Sidhnai reach of the Ravi. It will command an irrigable area of 192 000 acres, and actually irrigate 48 000, in the Sarai Sidhu and Multan tahsils, with a supply of 785 cubic feet per second. The Ravi here is sometimes without flow for a month in the cold season, and its greatest discharge does not exceed 18 000 cubic feet per second. The proposed weir will be 770 feet long, the length of main canal 40 miles, and of distributaries 80 miles. The fall of the Ravi appears to be 0·08 per thousand; while that of the main canal will be 0·125 for some distance, and afterwards 0·174 per thousand. This project, drawn up by Mr. L. F. Maclean, seems well considered, and very advantageous to the cultivation of this dry region.

The Swat Canal.—The surveys for this project commenced in 1871. The supply of water to be drawn from the Swat River is for the irrigation of wheat in the Yusufzai district of the Peshawur valley, lying to the east of the rivers Swat and Lundi. Details are not available.

Canals in Sind.

The Sakkar and Shahdadpur perennial canal, from the Indus in Sind, commenced in 1861 with an estimate of £72 982, was opened in 1870; it is 63 miles long, will irrigate 140 000 Sindian bigas of land, and is expected to yield a revenue of £210 000.

The Sind Inundation Canals are of native origin, their names and lengths in 1872 are as follow:—

West of the Indus.	Head.	Length in Miles.	
The Sind ...	21 miles below Sakkar ...	66	3 branches.
The Ghár ...	23 miles below Sakkar ...	...	2 branches.
The Western Nára	27 miles below Sakkar ...	70	300 ft. wide.
The Bigari ...	unknown ...	48	40 ft. wide.

East of the Indus.	Acres.
The Eastern Nára, Rori, improved in 1859.	
The Mitrau branch of the E. Nára (British), 190 miles, irrigates	157 000
The Thar branch of the E. Nára ... ,,	38 000
The Fuleli ... Natural branch of Indus irrigating Haidarabad.	

It is very doubtful whether a large proportion of these canals are not improved natural channels; there is very little information about the irrigation effected by them; they will probably be made eventually to serve as distributaries to perennial canals, having their heads at Sakkar, at Jhirk, 250 miles below it, and at Kotri.

Between 1872 and 1882, these canals have been improved and extended; they now can irrigate about two million acres. There is no detailed information forthcoming about the progress of the works, and the development of their construction. Probably most of the canals are now perennial. The actual condition as regards irrigation effected and revenue obtained is shown in the following statistics.

Canals in Sind.—Area of Cultivation and Revenues.

Year.	Kharif.	Rabbi.	Total. Government.	Jaghir.	Total of all Sorts.	Share of Consolidated Revenue.*	Total Canal Revenues.	Maintenance and Repairs, &c.
	Acres.	Acres.	Acres.	Acres.	Acres.	£	£	£
1876–77	1 291 273	418 948	1 710 221	—	—	—	—	113 079
1877–78	1 093 900	202 165	1 296 065	122 798	1 418 863	266 400	274 062	113 494
1878–79	1 333 546	551 769	1 885 315	130 774	2 016 089	295 716	304 043	110 851
1879–80	1 114 510	228 243	1 342 753	111 275	1 454 028	277 208	285 321	116 398
1880–81	1 172 384	156 278	1 328 662	164 007	1 492 669	284 307	294 403	118 961
1881–82	1 260 108	158 821	1 418 929	183 057	1 601 986	334 023	345 702	137 301
1882–83	1 281 691	226 601	1 502 292	165 001	1 673 293	325 252	338 931	136 368

* This is 90 per cent. of the net consolidated revenue, after deducting remissions.

Canals in Sind.—Statistics of Supply and Irrigation for the Kharif Season of 1882.

Group.	Canal.	Average Discharge.	Lift.	Flow.	Total.	Duty of 1 c. f. p. s.	Rainfall of the whole year in inches.
		Cubic ft. per sec.	Acres.	Acres.	Acres.	Acres.	
	Desert Canal ...	1 305	10 807	70 333	81 140	62	
Begari Canals	Muradwah ...	312	799	10 009	10 808	35	2·78 to 5·30
	Begari Canals ...	3 791	—	—	148 200	39	
Shikarpur Canals ...	Sind Canal ...	1 008	7 638	34 520	42 158	42	0·14 to 10·36
Eastern Nára Canals Tharspand Párkur ...	Mithrau Canal...	860	15 418	34 598	50 016	58	8·62 to 19·17
	Márak	1 395	46 256	894	47 150	35	
Haidarabad Canals ...	Ghalu	1 083	34 538	120	34 667	32	6·27 to 14·08
	Sarfaraz ...	482	20 649	221	20 870	43	
	Fuleli	6 366	57 224	95 251	152 475	24	
	Janamwah ...	228	4 773	2 628	7 401	32	
Fuleli Canals	Sanki Guni ...	541	45	4 522	4 567	8	0·46 to 12·72
	Sherwah ...	146	51	895	946	6	
	Aliwah... ...	182	10	1 698	1 708	9	

Canals in Sind.—Irrigation and Revenue in Year 1882–83.

Group.	Canal.	Length of Canal or of Band.	Kharif.	Rabbi.	Total.	Share of Net Consolidated Revenue.
		Miles.	Acres.	Acres.	Acres.	£
Begari Canals	Desert Canal	102	67 933	3 936	71 869	11 890
	Begari Canal	148	97 556	5 976	103 532	18 798
	Kashmor Band	(47)	33	612	645	114
Shikarpur Canals	Canals in Rohri	212	37 210	14 138	51 348	10 847
	Bands in Rohri	(54)	3 222	599	3 821	722
	Sind Canal	67	42 158	7 799	49 957	11 527
	Sakkar Begari Canal	(36)	—	—	—	—
Ghar Canals	Sakkar Canal	127	56 024	17 259	73 283	15 398
	Ghár	283	207 700	22 565	230 265	65 222
	Nára	217	91 636	31 173	122 809	33 827
	Wáhur	23	8 137	1 540	9 677	2 234
	Márui	15	2 439	1 259	3 678	1 024
...	Bands, right bank	(108)	12	—	12	4
Eastern Nára Canals.	Nára Supply Channel ...	12	31	31	62	14
	Eastern Nára	(110)	1 198	6 668	7 866	1 063
	Mithrau Canal	141	49 825	7 168	56 993	9 243
	Thar Canal	52	7 286	1 864	9 150	1 611
	Dimwah	18	919	211	1 130	215
	Heranwah	3	130	6	136	25

Haidarabad Canals.	Mihrabwah	59	8 966	2 678	11 644	2 794
	Nasrat...	66	15 925	6 726	22 651	5 932
	Naolakhi	137	34 132	6 039	40 171	10 930
	Daimbro	56	4 850	777	5 627	1 607
	Dad	105	16 545	2 700	19 245	4 493
	Rein	134	9 486	853	10 339	2 160
	Alibahr Kacheri	56	7 830	5	7 835	1 526
	Márak	194	40 971	113	41 084	9 151
	Gharo Mahmuda	291	37 974	3 707	41 681	7 995
	Khari Shumali...	214	27 450	492	27 942	3 869
	Násir	128	23 659	1 362	25 021	4 035
	Sarfaraz	116	17 079	625	17 704	2 482
	Other canals	112	17 268	3 938	21 206	5 426
Fuleli Canals ...	Fuleli and other canals ...	1 147	160 172	11 930	172 102	34 407
Karachi Canals.	Nára	106	36 083	36 270	72 353	14 825
	Phitta	27	4 335	1 577	5 912	1 373
	Canals north of Kotri... ...	58	10 075	3 802	13 877	2 890
	Kabri	136	7 913	1 815	9 728	1 905
	Baghár...	114	12 222	3 749	15 971	3 052
	Uchita	44	11 729	586	12 315	2 964
	Canals in Tatta, &c.	96	6 911	1 323	8 234	1 252
	Pinyari	369	49 534	4 734	54 268	7 781
	Canals in Mirpur Batoro ...	99	8 576	1 118	9 694	1 565
	Canals in Sujáwal	51	6 015	4 723	10 738	881
	Satta	58	7 699	726	8 425	1 662
	Canals in Játi	11	1 452	273	1 725	322
	Khauta	59	6 216	177	6 393	976
	Kokowari	100	14 475	663	15 138	2 612
	Canals Shahbandar	32	2 258	213	2 471	448
	Bands, right and left bank ...	(83)	442	103	545	158

Revenue of Irrigation Works in Sind for the Year 1882–83.

Canals.	Capital Outlay. During Year.	Capital Outlay. To end of Year.	Gross Revenue.	Working Expenses.	Net Revenue.	Interest.	Net Profit.
	£	£	£	£	£	£	£
Desert Canal	14 256	97 660	11 173	2 174	9 000	3 487	5 512
Begari Canal	9 742	142 583	19 605	8 915	10 690	5 341	5 349
E. Nára Works	20 226	393 025	13 921	7 098	6 823	14 709	−7 885
	44 223	633 268	44 699	18 186	26 513	23 537	2 976
Sakkar Canal	4 280	133 587	6 706	5 881	825	4 960	−4 134
Ghár Canal...	199	44 098	51 538	14 605	36 933	1 662	35 271
Alibhar Kacheri	—	2 392	759	469	289	93	196
Márak Canal	6	20 115	6 318	1 720	4 599	774	3 824
Sarfaraz Wah	—	12 468	1 420	1 179	241	474	− 323
Fuleli Canal...	—	112 085	15 872	16 705	−833	4 270	−5 103
	4 485	324 744	82 613	40 559	42 054	12 233	29 820
Grand Total ...	48 709	958 012	127 312	58 745	68 567	35 770	32 797
Other Works	No Capital Account.		151 754	76 373	75 381	—	—
Agricultural Works... ...	,,	,,	243	16 514	—	—	—

Canals in Guzrát.—The Háthmathi Channel and the Khari Cut, are canals in the basin of the Sabarmatti and in the Ahmadabad district under the Government of Bombay, although in North-Eastern India, north of the Vindhyan range. They are also near the smaller Ahmadnagar. The Háthmathi Channel is 21 miles long, and commands 44 744 acres, with a discharge of about 50 cubic feet per second. The Khari Channel is 4 miles long, and commands 3 890 acres. The two streams of supply have the same names. The Háthmathi and the Khari afford a very small amount of constant discharge, and are liable to high flood; hence the need of storage reservoirs, which are only now contemplated, though they should doubtless have been treated as the principal part of the works.

These so-called canals resemble the other canals of the Bombay Presidency in Southern India. Their petty size, as well as the conditions, show that they mostly are mere channels fit for carrying supply from tanks; but that the tanks were forgotten in the first instance. Such works are usually treated as simple storage works, not as canals. The above being in Guzrát are exceptional by locality; the following figures show their statistics :—

Statistics of Irrigation and Revenue from Canals in Guzrát.

Háthmathi Canal.	Capital.	Acres.	Revenue.		Working Expenses.	Rainfall.
			Assessment.	Receipts.		
	£		£	£	£	Feet.
Before 1875	—	—	—	98	—	—
1875–76	—	720	167	–69	1 333	2·4
1876–77	—	1 400	319	217	1 088	2·3
1877–78	—	1 043	222	354	466	1·2
1878–79	—	1 902	418	214	609	3·4
1879–80	—	1 187	338	517	968	2·6
1880–81	—	1 534	444	266	854	3·3
1881–82	—	2 521	522	394	733	3·0
1882–83	51 212	1 958	588	820	1 003	2·3
Khari Canal.						
Before 1881	—	—	—	—	—	—
1881–82	—	78	62	10	18	2·8
1882–83	11 744	378	197	60	2	2·9

North-Eastern India.

North-West Provinces.

The Eastern Jamna Canal is generally very similar in character to the Western Jamna Canal; it was constructed in about the same time and the same manner, being an old, fully developed, and very remunerative perennial canal: its cost was about two-thirds, and its average irrigated acreage about one-half of that of the latter. It is also a restoration and enlargement of an old native work, commenced by the British in 1823.

The first action in the matter by the British Government was the despatch of Lieutenant Tod, who made some surveys, followed by definite proposals, subsequently acted on; these surveys were continued by other military men. Captain Smith commenced the works in 1823, which were finished in 1830.

The Eastern Jamna Canal takes its supply from the Jamna at Kharrah and passes it down the old bed of the Jamna for 4 miles, to Nayashahr, where is the regulating dam with 30 sluices and head of the main canal. In the first 10 miles it crosses the mountain drainage at right angles, having dams at each of the torrents, and then continues on the highland of the country, on the watershed between the Hindan and the Jamna. The canal is in embankment for 40 miles, its water level being from 6 to 12 feet above the level of the country.

The course of the canal is through the Saharanpur and Muzaffarnager districts, into the Mirath district, where it tails into the Jamna at Salimpur.

In 1830, water was admitted through its main canal, after an expenditure on works of £31 124; in 1837, the capital account had increased to £46 000, and in that year, which was one of famine, it yielded £10 084 in water rate, and about the same amount in increased land revenue, or in all about £20 000 or 44 per cent.; the acreage then being only 96 000; the value of crops saved by irrigation was £488 494, or eleven times the cost of the canal. In 1846–47, the capital account was £81 460, and the acreage was 106 705, yielding £12 175 as water rate, and £14 965 as increased land revenue, or as gross returns 25 per cent. on the capital. The works completed up to that time were as follows:—Channels, main and branch, 465 miles; irrigation

outlets, 136; dams, 11; drainage outlets, 1; aqueducts, 7; bridges, 71; inlets and escapes, 26; falls, 14; mills, 12; workshops and station houses, 43.

As to the amount of irrigation effected by this canal in its earlier stages of development, comparatively little is known; in 1832–33 the tract irrigated was 276 square miles, yielding £248 177 in water rate, and £136 742 in increased land revenue; while in 1850–51, the irrigated tract was 497 square miles, yielding £384 919 in water rate, and the same amount of increased land revenue as in 1832. A portion of the canal was remodelled in 1854, and new escapes were made, which have since formed injurious swamps: in fact, even in 1872, the necessary drainage works can hardly be said to have been fairly taken in hand. From the year 1863–64 the water rates were enhanced, and the repairs to distributaries carried out by Government, and charged to maintenance; certain improvements were also effected by drainage works. At this period, a large amount of water was usually sold by contract, 288 villages taking it in that manner.

The acreage of the principal irrigated crops grown, of which wheat, barley, and indigo form the greatest portion of the Rabbi or cold weather crop, was as follows for four years:—

		1864–65.	1865–66.	1866–67.	1867–68.
Sugar-cane, annual...	...	28 530	29 034	20 847	26 987
Rice } Kharif	...	28 020	39 091	37 122	41 345
Cotton } Kharif	...	14 405	2 887	5 080	2 646
Wheat and barley ...	...	79 490	74 327	139 257	96 489

The canal system consisted in 1872 of 130 miles of channel and 625 of distributaries, watering a tract 120 miles by 15.

In 1871–72, the gross returns amounted to nearly 30 per cent. on the capital. The data of the works, the finance, and the irrigation for recent years will be found in the tabular statistics.

In 1876, a large amount was expended in drainage cuts, to very good effect.

In 1882, the mileage of canal was 130 miles, of distributaries 918 miles, and of drainage cuts 270 miles, in all 1 018 miles.

The Eastern Jamna Canal.—Abstract of Older Statistics.

Official Year.	Capital Outlay.			Working Expenses.	Direct Revenue	Indirect Revenue	Total Yearly Return.	Percentage of net Revenue of Capital.	Irrigation.
	Original Works.	Establishment & other charges.	Total to end of Year.						
	£	£	£	£	£	£	£		Acres.
1823 to 1830–31	31 124	12 726	43 800						
1830–31 to 1846–47	49 074	4 907	97 781	97 522	21 454				
1847–48	1 435	143	99 360	6 904	12 503	14 965	—	—	106 705
1848–49	3 254	325	102 939	7 042	15 055				
1849–50	3 460	346	106 745	8 016	16 183				
1850–51	304	30	107 079	7 392	15 914				
1851–52	2 558	256	109 893	7 726	13 079				
1852–53	3 057	306	113 256	8 279	17 325				
1853–54	5 315	531	119 102	7 872	14 993				
1854–55	16 376	1 688	137 665	9 565	14 479				
1855–56	12 691	1 637	151 994	8 188	9 688				
1856–57	5 180	691	157 865	13 540	12 997				
1857–58	1 351	223	159 440	7 691	6 645				
1858–59	2 260	337	162 036	9 255	12 483	—	—	—	154 006
1859–60	393	81	162 510	10 575	20 924	—	—	—	227 489
1860–61	973	141	163 624	11 376	28 941	—	—	—	261 327
1861–62	603	3 071	167 298	[illegible]	22 873	—	—	—	231 310
1862–63	1 346	– 300	168 343	[illegible]	25 696	[illegible]	29 496	13	184 232
1863–64	1 218	1 732	[illegible]	[illegible]	[illegible]	6 000	29 217	11	181 331
1864–65	3 366	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42 539	18	225 266
1865–66	2 876	[illegible]	[illegible]	[illegible]	[illegible]	6 000	47 463	20	160 355
1866–67	2 844	[illegible]	[illegible]	[illegible]	[illegible]	17 269	60 900	27	239 555
1867–68	4 930	[illegible]	191 328	[illegible]	56 560	17 769	74 329	33	182 544
1868–69	4 904	[illegible]	[illegible]	15 488	50 624	17 769	68 393	28	274 101
1869–70	2 779	282	[illegible]	16 508	65 728	17 769	83 497	34	251 067

Eastern Jamna Canal.—Supply of Water and Irrigation.

Year.	Supply passing Kulsiah.	Supply Utilised.	Kharif. Irrigation.	Rabbi. Irrigation.	Total Irrigation.	Double Cropped Land.	Distributaries open.	Mean Annual Rainfall.
	C.ft.p.s.	C.ft.p.s.	Acres.	Acres.	Acres.	Pr.ct.	Miles.	Feet.
1862–63	1 043	—	—	—	184 232	—	602	—
1863–64	932	—	71 129	110 202	181 331	—	602	—
1864–65	1 025	—	107 496	117 770	225 266	—	602	—
1865–66	—	—	80 225	80 130	160 355	—	596	—
1866–67	1 068	—	82 138	157 417	239 555	—	596	—
1867–68	—	—	78 606	103 938	182 544	—	596	—
1868–69	—	—	102 141	171 960	274 101	—	603	—
1869–70	1 020	—	119 163	131 904	251 067	—	606	—
1870–71	951	951	98 112	114 603	212 715	—	606	—
1871–72	982	938	72 404	120 345	192 749	—	606	2·3 to 5·0
1872–73	1 050	998	79 699	104 455	184 154	—	625	2·3 to 3·9
1873–74	—	—	70 478	97 570	168 048	—	—	—
1874–75	—	—	82 813	101 272	184 085	—	625	2·4 to 3·5
1875–76	—	1 079	87 294	108 552	195 846	—	619	2·5 to 3·1
1876–77	970	774	84 135	104 397	188 532	5·2	619	2·0 to 3·9
1877–78	—	989	103 632	103 100	206 732	—	618	—
1878–79	—	1 006	110 722	181 228	291 150	9·4	618	—
1879–80	—	1 042	98 032	142 201	240 233	5·8	618	—
1880–81	—	1 019	107 454	128 408	235 862	5·4	618	—
1881–82	1 118	1 001	104 197	150 689	254 886	5·5	618	1·9 to 2·6
1882–83	1 046	998	112 483	142 030	254 513	6·8	618	2·2 to 3·5

Eastern Jamna Canal.—Revenue Account in Pounds Sterling, based on Assessments.

Official Year.	Capital during Year.	Outlay, Total.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Returns.	Interest on Outlay.	Net Profit.
1868–69 ...	6 150	197 479†	15 405	62 545	17 769	—	—	—
1869–70 ...	3 061	200 539†	16 517	61 164	17 769	—	—	—
1870–71 ...	2 627	203 166†	18 175	56 637	17 769	—	9 729	—
1871–72 ...	2 275	204 935†	19 900	52 782	17 769	50 651	8 915	41 735
1872–73 ..	1 242	206 177	22 022	52 800	16 989*	47 759	9 310	38 449
1873–74 ...	1 565	207 742	20 984	54 922	16 989	50 926	10 099	40 827
1874–75 ...	11 728	219 469	20 327	62 137	22 153	63 964	8 716	55 248
1875–76 ...	12 274	231 743	23 027	62 580	22 153	61 706	9 972	51 734
1876–77 ...	23 450	255 193	21 473	57 796	22 304	58 627	10 545	48 082
1877–78 ..	6 043	261 236	20 357	60 543	22 362	62 549	11 317	51 232
1878–79 ...	1 714	262 949	20 411	78 522	22 448	80 559	11 794	68 765
1879–80 ...	2 721	272 414†	21 697	73 130	22 153	73 586	11 458	62 128
1880–81 ...	6 752	279 166	21 699	70 909	22 153	71 364	11 659	59 705
1881–82 ...	5 160	284 326	18 962	77 730	22 153	80 921	10 585	70 336
1882–83 ...	6 513	290 839	21 145	81 658	22 153	82 667	10 783	71 883

† Adjustments introduced.—Interest at 5 per cent. until 1870–71; at $4\frac{1}{2}$ in 1871–72. * Alteration in new accounts.

The Eastern Jamna Canal.—Capital Account to the End of 1872–73.

Detail.	Previous.	In 1872-73.	Total.
Works.	£	£	£
Main Canal.			
C. *Masonry works.*—Syphon ...	—	14	14
Bridge	103	583	686
Buildings		182	182
D. *Earthworks.*—Canal banks ...		49	49
Drainage works—sheds	545	44	590
Other works	158 737	—	158 737
Total Main Canal ...	159 385	872	160 257
Distributing Channels.			
The cost of these is not shown, they were made by the cultivators.			
C. *Masonry works*	—	683	683
D. *Earthwork*	—	120	120
Escape	45	220	265
Other works	8 936	—	8 936
Total on Works ...	168 366	1 895	170 261
Establishment.			
Direction	2 328	180	2 508
Executive	26 600	250	26 850
Total on Establishment ...	28 928	430	29 358
Tools and Plant	621	42	663
Profit and Loss	20	—	20
Fluctuations of Suspense Balance	7 000	−1 119	5 381
Less Receipts	—	−6	−6
Net Outlay ...	204 935	1 242	206 177
Add Simple Interest	243 272	9 310	252 582
Total Capital Outlay ...	448 207	10 552	458 759

Eastern Jamna Canal.—Remodelling Works. Outlay to end of 1882–83.

Detail.	During 1882-83	Total.
(2. MAIN CANAL.	£	£
B. Land	—	73
D. Regulators	11	225
E. Falls and Weirs	59	4 702
F. Torrent Works	(−563)	(−563)
G. Bridges	279	588
H. Escapes	162	162
I. Navigation	—	1 658
J. Mills	—	—
K. Buildings	(−157)	(−157)
L. Earthwork	487	3 558
	28	10 247
(3.) DISTRIBUTARIES.	709	4 892
(4.) DRAINAGE WORKS...	3 188	37 595
Total on Works	3 926	52 734
Total on Establishment ...	820	13 650
Tools and Plant	—	1 981
Suspense Account	436	3 733
(Capital Account is £272 194.) Net Outlay	5 182	72 098

Note.—The new classification of expenditure was adopted for the first time in the North-West Provinces in the accounts of the year 1878–79. After that year the progress reports take a diminished and altered form.

The Ganges Canal, commenced in 1848, and opened in 1845, is the third of the large perennial canals of Northern India made by the British. The earliest proposals leading to this work were that of Captain Debude in 1827, and the suggestions of Colonel John Colvin, before or about 1835, who recommended an offtake near Hardwar. The success following the opening of the East Jamna Canal in 1830, followed by the terrible famine of 1837–38 and its train of calamity, induced the Government to send Major Cautley to examine and report on the Hardwar site

in 1839. His proposal to make 256 miles of main canal and 73 miles of branches at an estimated cost of £260 000 was supported by the Court of Directors in 1841. A committee ordered to examine and report, recommended taking 6 750 cubic feet per second in a single main canal from Hardwar by the Solani course to Khanpur to supply irrigation to the whole of the Ganges Jamna Duab; which would yield £148 642 anually, apart from other receipts.

The works began in 1842, but were soon stopped. A general survey of this Duab was made in 1843-44; but Lord Ellenborough checked the whole by deciding on making it a purely navigable canal, directed to Allahabad. A mixed project was formed in 1845, and the works were abandoned on account of the Sikh war. In 1847 a committee recommended the resumption of the work as a purely irrigation-canal; and this was vigorously started. In 1848 Colonel Cautley resumed the charge of the works; some modifications in its alignment were made in 1850; and the canal was opened in April, 1854. It was very soon closed on account of the defective condition of the embankments near the Solani Aqueduct. After repairs, water was again admitted in November, 1854. A second closure was needful, and the canal was newly opened in April, 1855. Irrigation from it commenced in the month following.

During 1855, the area irrigated was 54 734 acres, besides a small supply to save crops from entire drought on 166 000 acres. At this time 450 miles of main canal were open, the mileage of the distributaries open being 225 at the beginning of the year, and 436 at the end of it; though as much as 633 miles were under construction. Most of the navigation then consisted in rafts of timber passing along the upper reaches down to Mirath; there was also some small boat traffic. The canal falls were also utilised for corn mills; and some revenue was obtained from the sale of grass and fuel grown.

In 1872, the canal resembled the Bari Doab Canal, being merely half-developed, in contradistinction to the Eastern and Western Jamna canals, which had their irrigation fully developed.

The principal head of the Ganges canal is about $2\frac{1}{2}$ miles above the sacred town of pilgrimage, Hardwar, or Hardiwar.

In the first 18 miles of its course the canal passes the Ratmu, the Ranipur and the Pattri torrents, the former torrent passing through at the same level, and the two latter in masonry superpassages over the canal. At the 18th mile, above Rurkhi, the canal crosses the Solani river in a masonry aqueduct; the embankments of approach are about 30 feet above the valley, and are 3 miles long; the aqueduct itself is 920 feet long, in fifteen arches of 50 feet span, and 30 feet in height. From this point onwards the main canal nearly follows the watershed between the Ganges and the Jamna for about 181 miles to Nanun, throwing off branches and cuts for irrigation and navigation. From Nanun the eastern branch, 170 miles long, continues to Etawah, where it falls into the Jamna, and the western branch of the same length continues to Khanpur, where it falls into the Ganges. There are also two smaller branches, 83 and 10 miles long respectively. This canal is of immense size; it carried a supply of 5 100 cubic feet per second in 1870, and utilised 90 per cent. of it; besides this it has an irrigating capacity of 1 205 000 acres. As to dimensions, the first four miles from Hardiwar are in natural channel, a branch of the Ganges. From Mayapur, where the artificial canal begins, and for a distance of 50 miles, the canal has a constant bottom width of 140 feet, a depth of 10 feet, and a slope of bed of 1·5 feet per mile. From the 50th mile where the Fattahgarh branch takes off, down to the 110th mile, where the Bulandshahr branch takes off, the bed-width is 130 feet, and the depth 9 feet: from the off-take of Bulandshahr branch to that of the proposed Koel branch, the bed-width is 110 feet, and the depth 8 feet; thence to Nanun the depth remains the same, but the bed-width varies from 96 to 80 feet. The Fattahgarh branch was in 1872 83 miles long, the Bulandshahr branch 54 miles long; the Khanpur and Etawah branches are each 80 feet in bed-width at their heads, diminishing gradually to 20 feet at their lower extremities.

Of the details of the works as originally contemplated, there is ample information given in the large work of Colonel Sir Proby Cautley, the designer and constructor of this canal, of whose energy, patience, and perseverance it is impossible to speak too highly, when reflecting on the difficulties, both political as well as other, that he had to encounter.

In spite, however, of the large amount of energy and money spent upon this canal, it is a particularly unfortunate one.

It was defective in several important respects, the inclination allowed to its bed was far too high, its bed retrogressed and its falls were damaged, so that it could not carry its full supply until about 1866, when a large additional outlay had been made. In fact, the whole of the canal, main and branches, had to be remodelled throughout; and the distributaries had been so badly laid out, that hundreds of miles of them have been abandoned at various times. The partial remodelling of the canal commenced in 1864; and it is to be hoped that it will eventually carry the full supply originally intended, without increasing the capital account, now £2 605 178, to much beyond £3 000 000. While 4 700 cubic feet per second is the highest amount of supply yet utilised on this canal, it is probable that eventually it may rise as high as 5 500, the supply for which it was originally designed and intended being 6 750 (or 7 000?) cubic feet per second; should it, however, after complete remodelling, arrive at that irrigating power, it will then have only six times the supply of the Eastern Jamna Canal, at a cost of about twelve times as much as that of the latter.

The acreage of the principal crops irrigated during four years was as follows:—

	1864-65.	1865-66.	1866-67.	1867-68.
Sugar-cane, annual	50 159	58 416	46 338	55 232
Rice } Kharif	22 466	23 134	30 539	36 365
Cotton } Kharif	42 026	10 496	19 094	5 616
Indigo	35 166	47 714	70 487	75 684
Wheat and barley...	338 971	362 679	400 444	319 715

About two-thirds of the irrigation effected by this canal is flush, or delivered at the ground surface, the remainder is delivered at a low level, the water being raised to the surface by native mechanical contrivances. In order to carry out the irrigation of the whole of the tract intended, it was proposed to make a secondary headworks at Rajghat on the Ganges, and to supplement the Ganges Canal by new works, named the Lower Ganges Canal; these were commenced in 1872.

From 1862 to 1873, the mileage of main canal was 519 miles; the branches 127 miles until 1867, when 8 miles were added.

In 1876, the works in progress were, permanent weirs and

dams to form headworks above Hardwar, some new weirs and locks, improvement and extension of distributaries, and a large amount of drainage cuts.

In 1880-81, the Khanpur and Etawah branches, with their dependent works, were transferred to form part of the Lower Ganges Canal.

In 1882, the mileage was 445 miles of main canal, 2 561 of distributaries, 867 of drainage cuts, in all 3 873 miles of channel of every sort.

Details of expenditure on works, and of irrigation during late years, are given in the tabular statistics.

Ganges Canal.—Expenditure of Water throughout 1871–72, *in cubic feet per second.*

Main and Branch Canals.	Kharif, 139 days.			Rabbi, 183 days.			Year, 322 days.			Annual Rainfall
	Entering.	Leaving.	Used.	Entering.	Leaving.	Used.	Entering.	Leaving.	Used.	Feet.
Northern	4 180	3 771	409	4 203	3 800	403	4 193	3 788	405	5·02
Fattahgarh Branch ..	220	—	220	205	—	205	211	—	211	2·14
Mirath „ ...	3 551	2 910	641	3 595	2 971	624	3 577	2 946	631	2·72
Bulandshahr „ ...	2 910	2 442	468	2 971	2 425	546	2 946	2 440	506	2·32
Aligarh „ ...	2 442	1 887	555	2 425	2 022	403	2 440	1 963	477	2.52
Khanpur „ ...	1 033	219	814	1 027	622	405	1 029	448	581	2·76
Etawah „ ...	854	483	371	995	544	451	934	521	413	3·52
			3 478			3 037			3 224	
Leaving Khanpur and Etawah Terminal Branches for purposes of Navigation.			702	...	...	1 166	...	..	969	
			4 180			4 203			4 193	

Ganges Canal.—Supply of Water and Irrigation. (Later returns.)

Year.	Supply passing Rurkhi.	Supply Utilised.	Kharif.	Rabbi.	Total Irrigation effected.	Double Cropped Land.	Distributaries open.	Mean Annual Rainfall.
	c.f.p.s.	c.f.p.s.	Acres.	Acres.	Acres.	p.c.	Miles.	Feet.
1862–63	4 850	—	90 693	114 912	205 605	—	2 266	—
1863–64	4 028	—	97 538	352 250	449 788	—	2 337	—
1864–65	4 026	—	161 835	404 682	566 517	—	2 440	—
1865–66	4 314	—	176 544	396 585	573 129	—	2 777	—
1866–67	3 940	3 507	181 658	453 076	634 734	—	3 039	2·15
1867–68	3 952	3 299	185 137	348 319	533 456	—	3 040	3·81
1868–69	4 946	4 649	344 266	734 133	1 078 399	—	3 112	1·32
1869–70	5 100	4 590	341 846	438 560	780 406	—	3 069	2·34
1870–71	4 299	3 827	266 682	499 932	766 614	—	3 069	3·16
1871–72	4 193	3 224	232 688	373 867	606 555	—	3 078	3·01
1872–73	4 787	4 221	247 191	437 979	685 170	—	3 118	2·75
1873–74	—	—	287 842	507 472	795 314	—	3 272	2·74
1874–75	—	—	288 615	608 815	891 430	—	3 346	3·27
1875–76	5 051	—	317 325	571 842	889 167	—	3 386	2·53
1876–77	4 779	—	316 282	592 951	909 233	—	3 403	2·31
1877–78	4 895	—	541 313	503 700	1 045 013	—	3 417	1·27
1878–79	5 034	—	483 356	725 872	1 209 228	20·0	3 538	1·95
1879–80	5 103	5 072	401 529	557 316	958 845	17·1	3 652	3·02
1880–81*	—	3 835	305 554	359 373	* 664 927	15·6	2 554	—
1881–82	5 018	3 598	296 554	475 837	772 391	19·2	2 554	—
1882–83	5 012	3 702	335 570	520 465	856 035	—	2 560	—

* Transfer of portion to the Lower Ganges Canal.

Ganges Canal.—Revenue Account in Pounds Sterling, based on Assessments.

Official Year.	Capital during Year.	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Revenue.	Interest on Outlay.	Net Profit.
	£	£	£	£	£	£	£	£
1862–63 ...	—	2 006 339	71 088	53 228	1 689	—	—	—
1863–64 ...	123 481	2 129 820	55 954	77 339	5 989	—	—	—
1864–65 ...	41 910	2 171 730	80 768	99 086	7 232	—	—	—
1865–66 ...	23 846	2 195 576	75 076	136 450	7 232	—	—	—
1866–67 ...	—	—	76 387	153 373	17 964	—	—	—
1867–68 ...	—	—	—	136 352	18 078	—	—	—
1868–69 ...	—	—	79 422	244 156	18 216	—	—	—
1869–70 ...	—	—	93 195	189 138	18 348	—	—	—
1870–71 ...	—	2 418 534	87 725	191 032	20 298	—	120 122	—
1871–72 ...	40 859	2 576 730*	91 670	157 904	22 934	89 168	109 339	(–20 171)
1872–73 ...	28 448	2 605 178	99 539	170 303	34 427	105 191	116 660	(–11 469)
1873–74 ...	39 447	2 644 625	93 526	201 427	38 171	146 072	127 926	18 146
1874–75 ...	123 096	2 767 721	98 763	221 665	56 185	179 086	111 707	67 379
1875–76 ...	58 759	2 826 480	105 462	216 607	62 580	173 725	121 949	51 776
1876–77 ...	128 134	2 954 730	105 039	224 018	66 838	185 816	124 620	61 196
1877–78 ...	100 285	3 055 015	97 870	249 641	67 647	219 418	130 146	89 272
1878–79 ...	99 112	3 154 127	96 805	295 157	70 914	269 266	139 706	129 561
1879–80 ...	32 084	3 254 775	119 308	253 678	66 893	201 263	135 521	65 742
1880–81 ...	21 650	2 724 334	88 603	184 380	44 301	140 078	114 766	25 312
1881–82 ...	15 588	2 739 306	88 223	219 288	44 301	175 467	102 708	72 659
1882–83 ...	27 759	2 767 065	88 016	244 284	44 301	200 568	103 533	97 036

The returns for 1862 to 1867 are approximate. * Adjustments...2 459 394. Interest at 5 per cent. in 1870–71; at 4½ in 1871–72.

The Ganges Canals..—Capital Account to the End of 1872–73.

Detail.	Previous.	In 1872-73.	Total.
Works.	£	£	£
(1) Head Works			
C. *Masonry Works.* Weirs... ...		2 457	2 457
(2) Main Canals and Branches ...			
B. *Cost of Land*		8	8
C. *Masonry Works.* Falls and Wiers		8 559	8 559
Bridges		11 894	11 894
Buildings		289	289
Navigation Works		534	534
D. *Earthworks.* Canal Embankments, &c.		620	620
F. *Miscellaneous.* Loss on Bricks...		1 557	1 557
Escapes		1 077	1 077
Drainage Works		1 856	1 856
Other Works (?)	1 698 817	...	1 698 817
Total Main Canal and Branches ...	1 698 817	28 851	1 727 668
(3) Distributing Channels.			
Preliminary Operations ...		234	234
B. Cost of Land		944	944
C. Masonry Works		4 570	4 570
D. Earthworks		4 155	4 155
(4) Other Works (?)	450 169	...	450 169
Total on Works ...	2 148 986	38 754	2 187 740
Establishment.			
Direction	55 081	1 615	56 696
Executive	232 302	3 866	236 168
Remodelling	16 671	...	16 671
Total on Establishment ...	304 054	5 481	309 535
Tools and Plant	16 725	1 473	18 199
Profit and Loss	7 101	...	7 101
Fluctuations of Suspense Balance	109 146	-17 153	91 993
Less Receipts	-9 282	-107	-9 389
Net Outlay ...	2 576 730	28 448	2 605 178
Add Simple Interest	1 941 670	116 660	2 058 330
Total Capital Outlay ...	4 518 400	145 108	4 663 508

Ganges Canal.—Remodelling and Extension Works. Outlay to End of 1882–83. (By Progress Report.)

Detail.	Head-works.	Main Canal.	Deobaud Branch.	Anupshahr [illegible]	Mát Branch.	Dasna Channel.	Bulandshahr Branch.
	£	£	£	£	£	£	£
A. Preliminary	—	—	437	2 [illegible] 5	636	—	—
B. Land...	—	19	1 839	2 07[illegible]	—	—	—
C. Masonry Work	18 882	—	—	–	—	—	—
D. Regulators	—	12 345	1 124	[illegible]1	82	—	—
E. Falls and Weirs	—	66 154	—	288	—	—	—
F. River Works...	—	12 942	17 040	2 928	—	—	—
G. Bridges	—	1 854	4 252	13 611	—	—	—
H. Escapes	—	30 368	1 080	17 459	1 479	—	—
I. Navigation	—	29 023	—	3 859	—	—	—
J. Mills...	—	—	—	—	—	—	—
K. Buildings	272	1 400	2 993	4 699	—	—	—
L. Earthwork	—	14 141	6 023	19 832	4 248	—	—
M. Plantations	—	—	—	—	—	—	—
O. Miscellaneous	—	6 753	549	2 140	—	—	—
P. Maintenance...	—	—	198	1 592	—	—	—
Totals...	19 154	175 005	35 560	84 193	6 444	—	—
Distributaries	—	27 130	9 413	30 251	—	—	10 768
Drainage and Protection	—	55 170	50	2 653	—	—	28 018

Total on Headworks and Canals	£320 357	Total on Works	£483 810
" on Distributaries	77 562	" Establishment	106 688
" on Drainage and Protection	85 891	" Tools and Plant	12 230
		Suspense, less Receipts	17 008
		Net Outlay	£619 736

The Lower Ganges Canal.—This is now treated as a work separate from the original Ganges Canal, to which it is an adjunct. The unfortunate condition of that great canal caused a committee to recommend, in 1866, that a further supply, or a second canal, should be taken from the Ganges at Rajghat, with which the lower part of the Ganges, Jamna Duab, should be irrigated, thus relieving the original canal. Colonel Strachey, R.E., made a definite project of construction in 1869; this was further developed by Major Jeffreys, R.E., and Colonel Brownlow, R.E. The design arranged for a supply equal to that of the old canal, namely 6 500 cubic feet per second in the rainy season, and 3 500 in the dry season, from permanent headworks. These, with 555 miles of main canal and accessories, were estimated to cost £1 825 845, and yield a net income of £195 000. But the actual cost of the old Khanpur and Etawah branch canals thus absorbed, amounting to about £400 000, was to be debited to its capital account.

These works commenced in 1872, and the headworks were finished in 1877. The river was diverted in course between Rajghat and Narora, where the Weir and off-take were made. The weir, estimated to cost £316 500, is a substantial one, resting on cylinders 20 feet deep usually, but those near to the under-sluices, or 56 out of 366, rest on the clay, and are 32 feet deep. The front and rear curtain walls rest on wells, driven down to the firm clay stratum. The weir is 3 800 feet long, in section 10′ × 10′; below it is a paved floor at 3 feet below dry-weather water level. Most of the material is brick; concrete is also used. The foundations of some parts consist of blocks, 10′ × 10′ × 10′. The weir sluices on the flank next to the off-take are 42 in number, each 7½ feet wide. The off-take has 30 openings, each 7 feet wide; the entrance lock, at some distance from it, has a chamber 150 × 20 feet. The sill of the canal entrance is nearly at low-water level of the river. The weir crest is 6½ feet above it, and this may be raised to 10 feet by shutters.

The main canal, for the first 26 miles, has a bed-width of 216 feet, a depth of water in full supply of 10 feet, and a slope of nearly 0·1 per thousand. It will continue, after throwing off branches, with a reduced section, giving a navigable communication with Allahabad, where it terminates. One branch will

supply water to the old Khanpur and Etawah branches. This will be navigable, and will maintain the navigable condition of those branches. Other branches are the Bhognipur, the Ghát-ampur and the Jhínjak branches, intended chiefly for irrigation.

In 1877 the project seems to have been modified and recast, the revised scheme being intended to bring under irrigation 462 000 acres of kharif crop, and 740 000 acres of rabbi crop, as the utmost possible.

At the end of 1878 about 100 miles of main canal were excavated and water admitted.

The accounts were separated from those of the Ganges Canal entirely in the year 1880–81, the arrangement having then been made that the Khanpur and Etawah branches, with their irrigation, were transferred, and that 1 000 cubic feet per second of supply should be passed from the Upper to the Lower Ganges Canal. The new divisions of the canal consisted then of the Narora, Mainpuri, and Bhognipur divisions, besides the two old ones.

In 1882–83 the mileage comprised in the Lower Ganges Canal consisted of 556 miles of main canal, 1 742 of distributaries, 249 of drainage cuts; in all, 2 547 miles.

The discharges of the Ganges were approximately determined at Narora, throughout the year 1882, from gauge-readings and declivities, as follow:—

Above Weir.		Above Weir.		Below Weir.	
Date.	Cubic ft. per sec.	Date.	Cubic ft. per sec.	Date.	Cubic ft. per sec.
3 January ...	2 301	5 April ...	2 728	24 November	3 468
20 „ ...	3 939	17 „ ...	2 681	28 „	3 506
3 February	3 098	25 „ ...	4 117	30 „	2 768
2 March ...	3 314	8 May ...	1 936	2 December	2 838
7 „ ...	2 876	14 „ ...	1 521	4 „	2 773
13 „ ...	2 260	15 „ ...	3 250	6 „	2 805
22 „ ...	1 739	23 „ ...	3 223	11 „	2 463
27 „ ...	1 562	20 December	2 170	18 „	2 309

Lower Ganges Canal.—Supply of Water and Irrigation.

Year.	Divisions of the Series.	Average Supply. c. f. p. s.	Kharif.	Rabbi.	Total.	Double cropped land.	Distributaries Open	Canal open.
			Acres.	Acres.	Acres.	per cent	Miles.	Miles.
1880–81	Old Div.	—	155 257	283 251	438 508	—	—	—
	New „	—	28 713	117 250	144 963	—	—	—
	Total	2 513	183 970	400 501	583 471	—	1 442	494
1881–82	Old Div.	—	138 045	278 421	416 466	—	—	—
	New „	—	66 527	148 223	214 750	—	—	—
	Total	2 955	204 572	426 644	631 216	22	1 623	531
1882–83	Old Div.							
	New „							
	Total	3 050	199 115	406 910	606 025	24	1 742	555

Lower Ganges Canal.—Revenue Account in Pounds Sterling, based on Assessments.

Year.	Capital expended	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue	Net Returns.	Interest.	Net Profit.
	£	£	£	£	£	£	£	£
1880–81	182 438	2 373 153	43 609	131 539	20 783	108 712	95 180	13 532
1881–82	117 024	2 490 793	54 548	151 956	20 783	118 391	90 231	28 160
1882–83	98 832	2 589 624	67 181	153 609	23 783	107 211	94 177	13 034

Lower Ganges Canal.—Outlay to End of 1882–83. (By Progress Report.)

Detail.	Head Works.	Main Line.	Fatahgarh Branch.	Bewar Branch.	Supply Branch.	Khanpur Branch.	Etawah Branch.	Bhognipur Branch.
	£	£	£	£	£	£	£	£
A. Preliminary ...	4 264	1 402	317	245	60	83	5	143
B. Land	1 482	17 044	5 860	9 050	3 608	111	—	12 986
C. Masonry Works	335 930	—	—	—	—	—	—	—
D. Regulators ...	—	25 320	2 275	2 809	14 485	476	1 278	4 831
E. Falls and Weirs	—	—	809	—	7 157	10 244	5 142	64
F. River Works ...	—	60 782	2 449	4 045	26 863	—	—	20 138
G. Bridges ...	—	30 812	13 309	19 374	14 660	43 976	7 528	52 550
H. Escapes ...	—	15 143	3 715	3 163	—	481	1 269	30 887
I. Navigation ...	—	14 729	—	—	1 290	22 179	—	—
J. Mills	—	—	—	—	—	1 140	—	—
K. Buildings ...	—	6 923	3 587	3 409	1 463	3 734	2 396	7 447
L. Earthwork ...	—	270 852	21 085	57 582	31 304	3 730	9 696	55 066
M. Plantations ...	129	3 586	1 340	3 272	944	—	—	5 224
N. " ...	—	—	—	—	—	—	—	—
O. Miscellaneous	40	240	72	38	—	256	3 079	295
P. Maintenance ...	6 734	4 266	978	1 038	102	—	—	455
	369 847	451 099	55 798	104 016	101 937	86 408*	30 392	190 084

Total on Headworks and Canals ...	£1 389 580
On Distributaries	176 107
On Drainage Works	16 508

With adjustments the Capital Account is £2 309 992.

Total on Works	£1 582 195
Establishment	326 692
Tools and Plant	114 090
Suspense	33 148
	2 056 125
Receipts on Account... ...	− 18 854
Net Outlay	£2 037 271*

* Incomplete.

The Agra Canal is a modern perennial canal irrigating a tract on the right bank of the Jamna, between it and the Khari Naddi, from below Delhi to the Utangan river below Agra.

The total length of main canal is 140 miles, its bed-width at the head, 70 feet; its supply 1 100 cubic feet per second in the Rabbi season, and 2 000 cubic feet per second in the Kharif season, requiring respective depths of 7 and 10 feet. The irrigable area is about 1 200 square miles, of which about one-tenth was unculturable waste, and one-fifth was irrigated from wells.

The supply of the Jamna at Okla having been found to fall occasionally below 800 cubic feet per second, in May, 1870, having been only 472, and in January, 1871, only 756 cubic feet per second; the supply of the Hindan, which is capable of giving 300 cubic feet, was also used in supplementing the canal, giving altogether 800 cubic feet as a certain minimum supply, according to which the depths needful for navigation are determined.

The fall of the canal from the head to the 32nd mile is 0·5 feet per mile; at this point is an overfall of 5·75 feet, and beyond that to the 86th mile, the gradient is 1·0 per mile; after which it varies from 0·33 to 1·00 feet per mile; below the 117th mile it becomes a simple distributary.

The intended depths, discharges and velocities are as follow:

Mileage.	Bed width. Feet.	Depths. Feet.	Mean Velocities.	Discharges. c.f.p.s.
Head to 32 ...	70	5·8 10·6	1·82 2·36	800 min. 2 000 max.
32 to 40 ...	58·8	4·1 7·0	2·25 2·76	587 „ 1 262 „
40 to 50 ...	53·4	4·3 7·2	2·29 2·88	574 „ 1 239 „
50 to 60 ...	47·4	4·1 6·9	2·28 2·82	485 „ 1 044 „
60 to 70 ...	41·4	4·1 6·8	2·27 2·75	429 „ 910 „
70 to 80 ...	30	4·2 6·8	2·26 2·69	326 „ 670 „
80 to $85\frac{3}{8}$ ...	24·2	4·4 6·6	2·20 2·62	276 „ 535 „
$85\frac{3}{8}$ to $95\frac{6}{8}$ ...	24·2	4·9 7·0	1·24 1·41	176 „ 309 „
$95\frac{6}{8}$ to 100 ...	24·2	4·8 7·0	1·22 1·41	172 „ 303 „

From 100 to 117 miles the bed widths vary from 21 to 18 feet; the depths from 3·7 to 5·2 feet, the velocities from 1·5 to 2·3 feet per second, and the discharge at the 117th mile is from 130 to 203 cubic feet per second.

The head works at Okla were begun at the end of 1868, and generally open in 1873; the supplementary headworks on the Hindan, below the Railway Bridge, are connected with the former by a canal having a bottom width of 24 feet, and discharging 291 cubic feet per second with a depth of 5·6 feet; it is 9 miles long, and enters the Jamna at one mile above Okla, where there is a lock to prevent the return of flood water. The distributaries have discharges varying from 140 to 25 cubic feet per second; the principal works, bridges, escapes, and weirs are comparatively inexpensive. The total estimated cost of the Agra canal was £540 188, of which £124 200 is that of headworks; the total area of irrigation is calculated at 704 000 acres, and the probable net income when the irrigation is fully developed is expected to be £51 375, in addition to £4 000 from navigation and mill rent—or about 10 per cent net.

Up to the end of 1872–73, the capital account stood at £432 267, of which £302 692 was incurred on account of works and plant, and £73 183 on establishment, this amount having been spent in five years. Of the above outlay, £30 131 was spent on plant, £106 444 on earthwork, £80 014 on falls and weirs, £37 736 on bridges, and £11 522 on buildings, and the remainder on miscellaneous works.

The formal opening of the Agra Canal was performed on 5 March, 1873–74. The supply passed down the canal to the 35th mile, where it was returned to the Jamna; the headworks were then complete excepting in lockgates. In 1874–75, all the works and distributaries of the first division of the canal were completed excepting the Hindan cut.

The works of the second division were completed at the end of 1876; and in 1877 navigation between Delhi and Matthra was opened.

In 1882 the mileage of the Agra Canal was 140 miles of main canal, 370 of distributaries, 17 of drainage cuts; in all 527 miles. The mileage of main canal having remained the same since 1878–79.

The discharges of the Jamna have been approximately determined from gauge readings and declivities at various sites, as follow :—

		C.f.p.s.	
At Khara	15 Jan. 1882.	3 243	J. Blandford.
At Khara	19 Dec. 1882.	2 928	"
At Okla, 2 miles below weir	12 Oct. 1882.	4 002	P. Denehy.
At Agra Taj	3 Mar. 1882.	5 350	G. E. Coles.
At Agra Taj	31 Oct. 1882.	1 840	"

Agra Canal.—Statistics of Supply and Irrigation.

Year.	Average Supply at head.		Irrigation.			Double cropped land.	Distributaries open.
	Kharif.	Rabi.	Kharif.	Rabi.	Total.		
	c.f.p.s.	c.f.p.s.	acres.	acres.	acres.	p. cent.	miles.
1873–74							
1874–75							
1875–76	917	944	5 656	21 578	27 234	—	231
1876–77	570	744	17 577	32 231	49 808	8·4	232
1877–78	—	—	57 652	105 981	163 633	—	—
1878–79	928	1 005	40 484	83 094	123 578	—	313
1879–80	788	982	20 911	36 286	57 197	—	329
1880–81	998	1 095	36 027	105 378	141 405	—	340
1881–82	1 040	1 029	56 497	96 106	152 603	7·8	348
1882–83	995	1 009	52 263	103 624	155 887	13·3	370

Agra Canal.—Revenue Account in Pounds Sterling, based on Assessments.

	Capital Expended.		Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Revenue.
	During Year.	Total.				
	£	£	£	£	£	£
1873–74						
1874–75	93 619	644 864	4 576	2 997	—	(−1 579)
1875–76	71 039	715 903	8 319	6 535	—	(−1 784)
1876–77	54 217	770 190	11 613	12 330	2 298	3 015
1877–78	34 289	804 479	15 792	40 691	2 503	27 402
1878–79	8 344	812 823	18 845	36 186	6 595	23 935
1879–80	3 089	838 058	23 549	21 150	—	(−2 399)
1880–81	3 437	841 495	21 995	48 495	—	26 500
1881–82	5 145	846 639	24 364	53 838	—	29 475
1882–83	5 574	852 213	22 940	58 242	—	35 303

Agra Canal.—Expenditure to End of 1875–76 on Works only.

(1.) *Headworks.*

	£
B. Land	762
C. Works—Okla weir, sluices, River band and works	79 472
Hindan cut, land and works	36 788
K. Buildings	2 519
P. Maintenance	9 044
	128 585

(2.) *Main Canal.*

A. Preliminary, surveys	836
B. Land	14 341
D. Regulators—one	680
E. Falls and Weirs—3 weirs, and 2 falls	6 134
F. Torrent works—1 syphon	8 528
G. Bridges—40 ordinary bridges, 26 smaller bridges	62 086
H. Escapes—4, with land and works	24 570
I. Navigation works—4 locks, Matthra Channel, Agra Channel	69 537
K. Buildings	11 620
L. Earthwork—excavation in 140 miles	101 443
N. Tanks and reservoirs—2	23 121
O. Miscellaneous	1 846
P. Maintenance and Repairs	7 031
	331 778

(3.) *Distributaries.*

Land works and earthwork in 15 distributaries	52 172

(4.) *Drainage* Works.

Surveys for Drainage	12
Total extraordinary	512 547
Total ordinary	10 835
Total Expenditure	523 382

Sardah Canal.—This scheme, projected in 1869, intended to provide irrigation in the Gogra-Ganges Duab, by a canal from the Sardah, near Naglah. This tract of 20 000 square miles is mostly in Audh, extending from above Sitapur to near Banáras; its ridge, throughout the greater part of its length, is from 50 to 70 feet above the Ganges. The supply of the Sardah is low from January to April; its lowest ordinary discharge at Banbasa is 5 500 cubic feet per second. This is small compared with that of the Korealli—11 000—and that of the Gogra, which at Bairam Ghat, near the confluence of the two, is 18 000 at their lowest. The supply of Sardah will hence not afford the amount required by the canal, 9 539 cubic feet per second; of which nearly half must be taken by supplementary offtakes from other rivers. The flood of the Sardah is about 74 000 cubic feet per second at Banbassa.

The estimate of the complete project appears to be about six millions sterling in cost, and £530 000 in net income after completion; the irrigable area being 2 384 750 acres. The project was drawn up by engineers Heaford, Handcock, and Scott, in or about 1871, with every possible detail, the scheme being generally based on that of Colonel Rundall and Sir Arthur Cotton, as well as on the original scheme of Lieutenant Anderson (Madras Engineers) drawn up in 1856–57.

The length of main canal above Minakot will be 21⅓ miles. There will be then three branches; one to Shahjahanpur of 63 miles, one to Faizabad of 207½, and one to Banáras of 360; the remaining branches, having different offtakes, proceed to Jaunpur, Lakhnau, and Azimgurh; these, with supplementary channels, give about 531 more miles of channel, or 1 169½ in all, besides 16 miles of escape channel.

The peculiarity of the present irrigation in Audh consists in its water being obtained principally from shallow wells, also from tanks and swamps, generally involving lift at all times, and entire drying up in seasons of drought. Five-sixths of the cultivable area is unirrigated.

The Eastern Ganges Canal.—Work on this project began in some excavation done in 1868–69 as a famine relief work; the cost of this, with the surveys, amounted to £21 382. The project

was recast in 1872. The present condition (in 1882-83) is unknown.

The Dun Canals consist of five perennial canals of an aggregate length of 66 miles in the Dera Dun, a valley of the Sawalikh, or lower Himalayas, north-west of Hardwar; they consist of:—

	Opened in	Miles long.	Discharge in 1872-73. C. f. p. s.	Supply utilised. C. f. p. s.
Bejapur	1840	11	39	30
Rajpur	1843	12	11	9
Kattapatthar	1854	19	33	17
Kallanga	1859	13	25	15
Jakhan	1863	12	15	9
Total		67	123	80

The financial state of these canals was, on April 30th, 1861:—

Canal.	Capital.	Interest and Repairs.	Revenue.	Deficit.
Bejapur	6 547	12 242	9 306	2 936
Rajpur	£4 024	£9 139	£8 495	£674
Kattapatthar	21 502	10 804	541	10 263
Kallanga	5 240	1 181	70	1 111
Total ...	37 313	33 367	18 382	14 985

At this time the acreage irrigated was approximately thus:— Garden land, 507 acres; rice, 1 974; tea, 570; wheat, 4016; in all 6067 acres; but the acreage of irrigated land was not fully measured until 1867.

The water rates were reduced in 1871, thus causing a temporary loss; but in 1874, after improvement, these canals yielded higher returns.

In 1882, the Dun Canals consisted of 66 miles of channel, all being termed distributaries; the reports show some improvements since 1872, but not any important new development of canalisation.

Dun Canals.—Supply of Water and Irrigation.

Year.	Average Supply.	Kharif Irrigation.	Rabbi Irrigation.	Total Irrigation.	Double-cropped Land.	Channels open.	Annual Rainfall.
	c.f.p.s.	acres.	acres.	acres.	p. cent.	miles.	feet.
1867–68	—	4 334	7 654	11 988	—	—	—
1868–69	—	—	—	—	—	—	—
1869–70	—	4 247	6 182	10 429	—	—	—
1870–71	—	4 524	7 569	12 093	—	—	—
1871–72	—	5 535	5 504	11 039	—	—	—
1872–73	123	5 217	8 785	14 002	—	67	—
1873–74	—	6 164	6 879	13 043	—	—	—
1874–75	—	5 615	10 020	15 635	—	—	—
1875–76	—	6 243	6 155	12 398	—	—	—
1876–77	—	5 726	6 869	12 595	—	—	—
1877–78	—	—	—	—*	—	—	—
1878–79	—	—	—	—*	—	—	—
1879–80	—	—	—	—*	—	—	—
1880–81	—	—	—	—*	—	—	—
1881–82	—	5 315	8 138	13 453	—	66	7·0
1882–83	142	5 523	9 445	14 968	—	66	4·8

* Incomplete or doubtful returns omitted.

Dun Canals.—Revenue Account in Pounds Sterling, based on Assessments.

Official Year.	Capital during year.	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Returns.	Interest on Outlay.	Net Profit.
	£	£	£	£	£	£	£	£
1863–64 ...	—	—	—	—	475	—	—	—
1864–65 ...	—	—	—	—	475	—	—	—
1865–66 ...	—	—	—	—	475	—	—	—
1866–67 ...	—	—	—	—	475	—	—	—
1867–68 ...	—	54 365	2 514	3 518	475	—	—	—
1868–69 ...	—	—	—	—	475	—	—	—
1869–70 ...	—	—	—	—	475	—	—	—
1870–71 ...	52	—	—	—	475	—	2 747	—
1871–72 ...	788	55 786	2 636	4 385	475	2 224	2 479	(–255)
1872–73 ...	1 152	57 253	2 547	4 982	475	2 909	2 544	365
1873–74 ...	654	57 907	2 751	4 995	475	2 719	2 592	127
1874–75 ...	1 753	59 661	2 681	5 228	1 595	4 142	2 624	1 519
1875–76 ...	942	60 603	2 539	4 845	1 595	3 901	2 679	1 222
1876–77 ...	698	61 301	2 755	4 945	1 663	3 853	2 715	1 138
1877–78 ...	1 152	62 453	1 898	4 500	1 688	4 291	2 754	1 537
1878–79 ...	724	63 177	2 442	4 977	1 748	4 283	2 827	1 457
1879–80 ...	(–221)	63 760	3 646	5 841	1 595	3 790	2 807	983
1880–81 ...	(–16)	63 743	3 852	5 448	1 595	3 191	2 802	389
1881–82 ...	(–29)	63 714	3 875	5 161	1 595	2 882	2 490	392
1882–83 ...	25	63 739	4 745	5 716	1 595	2 566	2 489	77

The Rohilkhand and Bijnaur Canals.—These consisted of a number of ancient, badly designed lines, which were worked at a loss in 1872, though after remodelling may yield very good results; they are:—

Rohilkhand	Baigul Group	108 miles.
	Kitcha Dhora Group	32 ,,
	Paha Group	13 ,,
	Kailas Group	32 ,,
Bijnaur	Nagina Group, Nehtor Group	38 ,,

The combined outlay till April, 1861, was £19 830; and in that year of extreme famine the income—£3 667—first exceeded the charges and maintenance—£3 274—as the irrigated acreage was nearly double the usual amount. But even then the average water rate was only eightpence per acre, though the staple crops of this province are rice and sugar.

The combined outlay up to 1872–73 was £103 600; the direct, indirect, revenue, and working expenses for the year—£3 438, £2 261, and £5 132 respectively; the acreage, Kharif 21 204; Rabbi 34 446; total 55 650 acres. The length of distributaries was increased from 180 miles in 1867–68 to 294 miles in 1872–73.

In 1882-83, the Rohilkhand Canals, apart from the Bijnaur Canals, consisted of 94 miles of main canal, and 225 miles of distributaries; in all 319 miles.

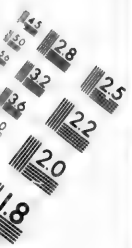
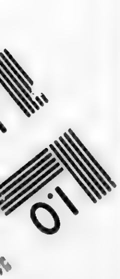
The following are the Channels or Rivers in detail:—

	Miles.		Miles.
Baror River	3	Bahgul Canal	115
Paha Canal	53	Absara River	—
Kicha Canal	81	Absara Channel ...	10
Dhora River	8	Nakatia River	—
Sankha River	—	Kailas Canal	73
Dhorania River ...	—		

In 1882–83 the Bijnaur Canals consisted of two canals, the Nagina Canal, having four distributaries of an aggregate length of 19 miles; and the Nihtor Canal, with three distributaries of an aggregate length of 14 miles; including the main channels in each case; these being each 9½ miles long.

IMAGE EVALUATION TEST TARGET (MT-3)

6"

Rohilkhand Canals.—Supply of Water and Irrigation.

Year.	Average Supply.	Irrigation.				Double Cropped Land	Distributaries Open.	Rainfall.
		Annual.	Kharif.	Rabbi.	Total.			
	C.ft.p.s.	Acres.	Acres.	Acres.	Acres.	Pr.ct.	Miles.	Feet.
1871–72	—	5 914	16 481	16 936	39 331	—	—	—
1872–73	—	—	—	—	—	—	—	—
1873–74	—	—	—	—	—	—	—	—
1874–75	—	—	—	—	—	—	—	—
1875–76	—	—	—	—	58 769	—	—	—
1876–77	—	—	—	—	74 319	—	—	—
1877–78	—	—	23 072	7 004	30 076	—	—	—
1878–79	—	—	21 679	57 237	78 916	—	—	—
1879–80	—	10 257	8 770	66 231	85 258	—	—	—
1880–81	—	10 239	47 162	30 228	87 629	—	—	—
1881–82	—	8 876	27 221	48 369	84 466	—	—	—
1882–83	—	11 306	21 368	46 833	79 507	—	225	—

* NOTE.—The accounts of the Bijnaur Canals were formerly mixed with those of the Rohilkhand Canals.

Bijnaur Canals.—Supply of Water and Irrigation.

Year.	Kharif.	Rabbi.	Total.
	Acres.	Acres.	Acres.
1875–76	—	—	3 046
1876–77	—	—	4 433
1877–78	—	—	—
1878–79	—	—	—
1879–80	656	1 730	2 386
1880–81	2 808	2 041	4 849
1881–82	2 894	2 136	5 030
1882–83	2 298	3 207	5 415

Rohilkhand Canals.—Revenue Account in Pounds Sterling, based on Assessments.

Official Year.	Capital during Year.	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Returns.
	£	£	£	£	£	£
1870-71 ...	4 039	56 359	—	—	—	—
1871-72 ...	9 397	65 756	8 062	2 288	1 351	(−4 423)
1872-73 ...	19 822	96 604	4 885	2 486	3 261	862
1873-74 ...	15 497	112 101	6 577	3 819	3 261	503
1874-75 ...	17 248	129 349	5 175	2 763	5 007	2 596
1875-76 ...	6 349	135 698	4 798	4 011	5 007	4 219
1876-77 ...	8 917	144 614	5 297	5 576	5 306	5 586
1877-78 ...	3 593	148 207	7 082	2 760	5 108	786
1878-79 ...	5 620	153 827	6 456	5 482	5 112	4 137
1879-80 ...	(−166)	159 244	7 744	6 193	5 007	3 456
1880-81* ...	(−252)	165 989	10 333	8 367	5 824	3 858
1881-82* ...	(−116)	165 873	12 339	7 510	5 834	995
1882-83* ...	2 752	168 625	11 288	7 011	5 824	1 547

* Bijnaur Canal included.

Bijnaur Canals.—Revenue Account in Pounds Sterling, based on Assessment.

Official Year.	Capital during Year.	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Returns.	Interest on Outlay.	Net Profit.
	£	£	£	£	£	£	£	£
1872-73	—	6 997	251	436	—	185	315	(−130)
1873-74	—	6 997	434	550	—	119	315	(−196)
1874-75	—	6 997	346	340	817	810	315	496
1875-76	—	6 997	237	432	817	1 013	315	698
1876-77	—	6 997	748	695	859	806	315	491
1877-78	—	6 997	610	609	857	855	315	540
1878-79	—	6 997	304	253	824	774	315	459
1879-80	—	6 997	261	348	817	904	315	589
1880-81*	—	—	—	—	—	—	—	—
1881-82*	—	—	608	789	—	—	—	—
1882-83*	—	—	1 047	660	—	—	—	—

* Included with Rohilkhand Canals again.

The Bandalkhand Canals, from the rivers Betwa and Dassan, proposed by the late Captain A. H. Bagge, of the Bengal Engineers, still remain as incompleted works; detailed surveys were, however, commenced in 1873.

In 1882-3, the Betwa Canal was partly constructed; the proposed site of weir for headworks being at Paricha.

The discharges of the Betwa were approximately determined in 1882 from gauge readings and declivities, thus :—

At Paricha.		At Moiat.	
Date.	Cubic feet per second.	Date.	Cubic feet per second.
22 July ...	560 575	12 October	1 503
26 " ...	543 429	25 "	896
21 " ...	426 348	25 November	394
17 " ...	290 630	12 December	335
20 " ...	286 831	16 January	193
16 " ...	278 455	4 February	145
19 " ...	80 959	20 March	31
15 " ...	85 514		
21 June ...	49 996		
12 July ...	12 110		
5 " ...	9 826		

The Sarun Canals.—The effect of the works is to supply four old river-channels, of a deltaic sort, with water from the Gandak; the irrigation is partly effected by lift, of 8 to 15 feet, and partly by backing up the canal water into natural channels; the supply is nearly perennial.

The irrigation from the Daha Canal, Ganduki Canal, Dhanaie Canal, and Gangri Canal in 1882–83 amounted to 1 741 acres, of which 1 099 was rice crop; the gross revenue was £1 803, the cost of maintenance £3 360.

Besides the above, much indigo is irrigated and not assessed, and water is supplied to indigo factories, for which no direct payment is made. In the true sense, these works are productive; according to the official sense, they are not.

Other projected canals in Bahar are the Tirhut; and the Hughli and Damudar projects in Bengal.

The Sohan Canals.—These constituting a portion of the Bahar project of Colonel Dickens, were designed to provide high-level navigation for 295 miles from Mirzapur on the Ganges through Dehri, the headworks on the Sohan, to Manghir on the Ganges, and to irrigate the country on both banks of the Sohan, between this line of navigation and the Ganges. The Western main canal, from Dehri to Mirzapur, was to be 125 miles long, commanding the irrigation of an area of 2 100 square miles; the Eastern main canal from Dehri to Manghir, 170 miles long, commanding 3 000 square miles. The main canals were designed to carry 5 300 cubic feet per second, with a depth of water of 9 feet, and a bottom width of 180 feet; in the Eastern canal the fall from the Sohan to the Ganges, of 123 feet, to be overcome by a series of locks. It was originally intended that these and other works should have been carried out with English capital, under the East India Irrigation Company in 1867; they were, however, commenced in 1870 by the Public Works Department, under Mr. Levinge, aided by about twenty English engineers.

The Western main canal was nearly completed to full dimensions for a length of 22 miles by the end of March, 1873; and its bridges and siphons were in progress. The Eastern main canal was then also nearly completed for eight miles. On the Arrah Canal, which is to be 70 miles long, and will irrigate 430 000 acres, ground had been broken over 60 miles; and six locks, two bridges, and seven siphons were in progress. On the Patna Canal, which will be 84 miles long, and will irrigate 390 000 acres, two-thirds of the earthwork was executed in 1872–73.

At the headworks, the masonry well-blocks of the upper breast-wall of the weir were sunk right across the river in 1870–71, and in 1871–72 those of the lower breast-wall, as well as parts of the head and under-sluices and head locks; the stone being brought by locomotives from quarries seven miles off.

The following is an abstract of the estimate of cost of the works:—

		£	£
295 miles of high-level main canal at per mile	...	4 000	1 180 000
240 miles of main irrigation and navigable canal, at		3 000	720 000
928 miles of main irrigation distributaries	... ,,	500	464 000
261 000 acres irrigated in detail	... ... ,,	2	522 000
326 250 acres of minor drainage works	... ,,	0 8s.	130 500
Headworks			225 000
Workshops, shelter, &c.			43 000
			3 284 500
Superintendence at 12·5 per cent.			410 500
Tools and plant			80 000
			3 775 000

The capital account is as follows:—

	Works and Plant. £	Establishment. £	Total. £
Up to April 1st, 1872	368 036	77 456	445 493
During 1872–73	210 951	40 635	251 587
Up to April 1st, 1873	578 987	118 091	697 079

The Sohan Weir is $2\frac{1}{3}$ miles long and 8 feet high, and is especially interesting as an example of the most modern construction, exhibiting like the weirs on the Orissa canals, also designed by civil engineers, a vast improvement over everything done before in works of this class in India. These canals were partly open in 1875, and were working in 1877; the details being according to the following tables.

Sohan Canals.—Lengths of Canal Open, &c., in 1882–83.

Series.	Navigable Canal.	Branches.	Dis-tributaries.	Area Commanded.	Area Irrigable.	Village Channels.
	Miles.	Miles.	Miles.	Acres.	Acres.	Miles.
Eastern Main and Patna Canal	86¼	—	311	307 610	263 840	182
Arrah Canal	74	70½	459½	441 500	311 000	702
Western Main and Baxar Canal	58½	77½	305	546 814	346 440	302
Total	218¾	148	1 075½	1 295 924	921 280	1 186

Sohan Canals.—Supply and Irrigation since 1877.

Year.	Canal.	Branches and Dis-tributaries.	Western Main.	Eastern Main.	Kharif.	Rabi.	Sugar.	Leased.	Hot Season.	Total.
	Miles.	Miles.	Cub. ft. per sec.	Cub. ft. per sec.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1875–76	87	190	—	—	—	—	—	—	—	—
1876–77	87	372	—	—	—	—	—	—	—	—
1877–78	173	567	—	—	107 087	124 818	9 891	—	—	241 790
1878–79	217	893	—	—	99 964	77 430	19 624	—	—	197 018
1879–80	217	957	—	—	41 132	62 266	27 158	—	—	130 556
1880–81	217	1 070	—	—	134 208	50 290	23 127	—	—	207 625
1881–82	217	1 182	— to 2 219	410 to 925	55 355	36 795	21 891	43 240	20 794	178 075
1882–83	219	1 224	660 to 1 250	151 to 924	65 514	15 999	15 275	74 555	2 481	173 824

The maximum canal supply is: Kharif, 4 766 cubic feet per second; Rabi, about 3 000 cubic feet per second.

Sohan Canals.—Revenue Account to the end of 1882–83.

Official Year.	Capital Outlay.		Water Rate.	Gross Receipts.	Maintenance.	Total Charges.	Net Profit.	Rainfall at Dehri.
	During Year.	Total.						
	£	£	£	£	£	£	£	Feet.
1875–76	—	—	5 087	5 090	—	—	—	4·2
1876–77	—	—	5 976	7 318	—	—	—	3·1
1877–78	—	—	5 965	10 129	—	—	—	2·8
1878–79	—	—	37 331	43 763	—	—	—	2·8
1879–80	—	—	44 472	53 159	—	—	—	4·2
1880–81	—	—	37 827	47 864	35 784	47 257	607	3·6
1881–82	—	2 329 345	60 393	73 629	32 803	45 732	27 897	2·5
1882–83	37 254	2 366 599	56 647	68 468	40 284	52 984	15 484	2·4

The Midnapur Canal and the Hijalli Tidal Canal.—The Midnapur Canal, opened in 1871, connects Midnapur with tide water in the Hughli, 16 miles below Calcutta, and forms a communication between that river and the Kusi, Rupnarain, and Damuda. It will be 52 miles long, and will effect the irrigation and drainage of 200 000 acres: it was in 1873 capable of irrigating 72 000, but its distributaries and drainage channels were still incomplete. Its estimated cost was £931 000. These canals are in Bengal proper; but as the account of these is in the earlier official records mixed with that of the Orissa canals, it will here also be found under that head until 1873. From 1867 to 1873, the works having been sold by the East India Irrigation Company to Government, were carried on by the Public Works Department. On 1st April, 1873, the capital account amounted to £695 812, including the Hijalli Canal; and the state of the works was thus:—

Canal.	Canal completed.	Distributary open per acre commanded.	Area for which water was provided.	Area commanded by Distributaries.	Cost of Canal per mile.	Cost of Distributaries per mile.
	Miles.	Miles.	Acres.	Acres.	£	£
Midnapur Canal	24	—	138 150	69 950	—	—
Hijalli Canal	62	—	11 500	2 000	—	—

The Hijalli Tidal Canal is nearly entirely for navigation between the Rupnarain opposite Diamond Harbor and the Burraballang at Balasur; half of it is thus beyond the Gangetic basin, in Southern India. It had 29 miles open for traffic, from 1873 to 1883; its capital outlay amounted to £177 270 in 1883. The expenses of removing silt are heavy. The annual gross revenue varies from £2 294 to £6 228; the total charges, from £1 243 to £4 436; about two-thirds of the weight of goods transported consist of articles of food; the estimated value of annual traffic varied from £133 944 to £415 535; the number of annual personal passages from 1 932 to 4 184.

The following statistics of the Midnapur Canals partly show the development of irrigation after 1873.

Midnapur Canals.—Supply and Irrigation until 1882–83.

Year.	Length.		Supply.		Irrigation.				
	Main Canal.	Distributaries.	Midnapur Weir.	Pauchkura Weir.	Under Midnapur Weir.	Under Pauchkura Weir.	From Tidal Reaches.	Total.	Annual Rainfall at Midnapur.
	Miles.	Miles	C.f.p.s.	C.f.p.s.	Acres.	Acres.	Acres.	Acres.	Feet.
1877–78	—	—	—	—	—	—	—	19 819	Average 4·7
1878–79	—	—	—	—	—	—	—	58 731	
1879–80	48	254	—	—	—	—	—	100 178	3·2
1880–81	48	267	—	—	—	—	—	103 862	4·9
1881–82	48	277	231	—	91 685	11 250	1 212	104 147	5·9
1882–83	48	277	361	71	90 036	10 947	956	101 939	5·5

The irrigation is almost all rice crop in the Kharif season.

Midnapur Canals.—Revenue Account until 1882–83.

Official Year.	Capital.		Water Rate.	Gross Revenue.	Maintenance	Total Charges.	Net Profit.
	During Year.	Total.					
	£	£	£	£	£	£	£
1873–74	—	—	3 582	7 264	10 371	12 032	def.
1874–75	—	—	6 702	11 622	11 232	13 043	"
1875–76	—	—	5 279	11 111	14 379	16 740	"
1876–77	—	—	6 146	13 699	14 689	17 128	"
1877–78	—	—	5 348	17 009	18 047	20 381	"
1878–79	—	—	8 501	17 071	15 081	17 284	"
1879–80	—	—	13 014	24 723	13 069	15 440	9 283
1880–81	—	—	11 296	21 647	16 568	18 922	2 725
1881–82	—	783 231	11 859	25 007	20 258	23 847	1 150
1882–83	12 178	795 410	10 406	26 801	20 364	24 650	2 151

SOUTHERN INDIA.

THE ORISSA CANALS.

Canals in the Orissa delta (also those in Bengal at Midnapur and Hijalli included in the general scheme until 1873).

The headworks proposed for these canals consist of three weirs across the Mahanaddi, the Katjuri, and the Beropa, 6 400, 3 900, and 1 980 feet long respectively; the two first 12·5, and the third 9 feet high; they are of modern design, having movable iron stanchions and shutters that admit of being lowered to allow floods to pass over them. The canal for the irrigation of the central delta, between the Mahanaddi and the Katjuri, is taken off from the right flank of the Mahanaddi weir, and a junction canal connects it with the Katjuri. The Taldandah Canal also takes off from the right flank, and runs to Taldandah, the limit to tidal navigation, and it, with its branch, the Machgong Canal, will eventually irrigate 155 000 acres of the central delta; they can, in 1873, irrigate 30 000, being in use for about one-third of their lengths, or 52 miles of each. Two canals are led off from the Beropa weir: the one from the left bank is the high-level canal, designed for navigation from Kattak to Calcutta; of this the first 32 miles to the river Brahmani are open, and the greater part of its distributaries for the irrigation of 80 000 acres are completed; the other from the right flank of the Beropa weir, intended to irrigate the country between the Mahanaddi and the Brahmani, is called the Kendrapara Canal; it is 160 feet wide and 7 feet deep, and is intended to irrigate 27 0000 acres of the northern delta, at a duty of 120 acres per cubic foot per second of supply; the distributaries have an aggregate length of 171 miles, and will irrigate 85 000 acres; also its Pattamandi branch taking off on the fourth mile, and running to a port on the estuary of the Brahmani, will irrigate 113 000 acres.

The present estimate of the cost of these works is £2 598 200, and they are intended to irrigate 1 600 000 acres.

The history of the Orissa Canals is as follows:—

The preliminary designs, drawn up by Col. Sir Arthur Cotton, in May, 1858, were estimated to cost £1 300 000, and intended to irrigate 2 250 000 acres. A charter was granted to the E. I.

Irrigation Company in June, 1861, and capital was raised to the amount of one million as a first issue. Surveys, preliminary designs, and estimates were drawn up afterwards under Col. Rundall by May, 1863; the estimate amounting to two millions, and the proposed amount of irrigation one and a half million acres, at a duty of 133 acres to one cubic foot per second.

Certain Initiatory Works were estimated in detail thus:—

	£
1. Headworks, comprising the Naraj Weir, the Mahanaddi anicut, the Beropa anicut, and the Kattak headworks, 1 500′ long × $7\frac{1}{2}'$ high	165 996
2. First Section of High-level Canal, 32 miles from the Mahanaddi to the Brahmani	58 449
Its distributaries, 112 miles for 87 000 acres	13 050
3. Kendrapara Canal, 40 miles, Kattak to False Point ..	33 537
Its distributaries, 180 miles for 270 000 acres ...	40 500
4. Midnapur Canal, $48\frac{1}{2}$ miles, Midnapur to the Hughli...	152 342
Its distributaries, 160 miles for 148 500 acres ...	22 275
5. Hijalli Tidal Canal, first two reaches, 27 miles from the Rupnarain	49 119
	535 268
Stores and management 30 per cent.	160 580
Surveys of general scheme, purchase of a fleet of boats, London Offices, and preliminary expenses had already cost...	123 935
Interest already paid to shareholders	112 477
Total estimated cost of initiatory scheme ...	£932 260

Estimated return.—Navigation to repay establishment and management, and the irrigation of 505 500 acres, at 5 Rs. per annum, to yield a gross return of 36 per cent. on the £695 848, and deducting 5 per cent. for repairs and maintenance, 31 per cent. net; or 21 per cent. on the million of total expenditure estimated.

The works were begun in December, 1863. Irrigation was first available in December, 1865, was first taken up in April, 1866, and began to yield returns in October, 1866. Navigation began to yield returns in March, 1865. The Company sold the Orissa undertaking in December, 1867; the works constructed and returns being as follows:—

The total amount of work done by May 31st, 1867, under the heads of the preceding estimate, was—1. Headworks open, but not complete. 2. High-level canal, 10 miles open, 12 nearly ready, and 17 miles of distributaries open. 3. Kendrapara Canal, 30 miles open, to a reduced width, and 72 miles of distributaries open. 4. Midnapur Canal, 28½ miles under construction, 10 nearly ready, and 46 miles of distributaries open; 5. Tidal canal, 27 miles open without locks. Water was then available for 153 400 acres of irrigation. Between May and December, 1867, further work was done on the above canals, details of which are wanting, as well as 23 miles of uncompleted work on the Taldandah Canal.

Expenditure up to October, 1867.

	£
Expenditure—on works up to June, 1867	620 000
" from June to October	187 936
" from October to December ...	not known.
Total expended on works in India	807 936
Total on all accounts	884 861
Balances	58 671
Receipts, not including Government loan of £120 000	£943 532

The earlier returns until October, 1867, were thus:—

Year.	Navigation. £	Water Rate. £	Total. £	Irrigation. Acres.
1863	876 ...	—	876	—
1864	843 ...	—	843	—
1865	1 089 ...	—	1 089	—
1866	1 145 ...	Oct. 878	2 043	2 346
1867	Aug. 1 669 ...	Feb. 1 208 Oct. 2 253	5 130	4 328 9 836
	5 622	4 339	9 981	—

In February, 1867, water was available for 60 000 acres, and in October, 1867, for 153 000 acres. In 1867 water for 13 000 acres, valued at £2 500, was stolen.

At the time of sale, the Company had water available for 200 000 acres, which at 5 Rs. per acre would yield £100 000, or about 10 per cent. on the total expenditure, had the cultivators

taken the water; as, however, they did not, and the Act had not then been issued (passed in February, 1870) to recover rates from land brought under water-command, it would have been unwise to extend the works, and the Company were then forced to sell up at par to the Government.

From 1867 to 1873, these works were carried on by the Public Works Department. On April 1st, 1873, the capital account of the Mahanaddi Project, including the Brahmani and Baitarni Series, amounted to £1 221 577; and the state of the works was thus;—

Canal.	Canal completed.	Distributary open per acre commanded.	Area for which water was provided.	Area commanded by Distributaries.	Cost of Canal per mile.	Cost of Distributaries per mile.
	Miles.	Miles.	Acres.	Acres.	£	£
High-level Canal	37	·0021	74 600	42 660	3 618	203
KendraparaCanal	40	·0032	313 000	100 000	2 116	129
Taldanda Canal	27½	·0042	155 000	15 336	1 398	109
Machgong Canal	6	·0040		16 829	716	95

The expenditure mentioned does not include establishment nor proportionate cost of headworks. The supply provided for the areas was at the irrigating duty of one cubic foot per second for 133 acres.

The discharge passing down the Kendrapara Canal varied from 500 cubic feet per second in August, to 126 in March, and in the high-level canal from 350 in July, to 115 in March; each of the canals were closed for repair for about two months in the cold weather.

In 1869, the water rates having been lowered from 10s. to 2s. per acre, the gross revenue amounted only to £441; in 1869-70 it amounted to £5 235; in 1870-71, the acreage actually irrigated was 22 128 acres; and in 1871-72 only 11 652 acres, demands for water rate being abandoned by the revenue collectors, and only £1 772 being actually collected.

The following tables indicate the extension of works, and financial condition of these canals from 1872 to 1882. It will be observed that the spread of possible irrigation has been small,

while the increase of actual irrigation has been large. The people, who have suffered greatly from floods for many years, perhaps for ages, were too stupid and ignorant to appreciate the advantages of irrigation, and refused to irrigate for many years The advisers of the Government, instead of striving to induce the spread of irrigation, recommended the tedious process of allowing the natives time to learn, and advised that the distribution works should not be extended. It appears that after these 10 years the natives began to learn, and then irrigated two-thirds of the area for which distributaries existed.

In 1881–82, when this stage had been reached, estimates for extending the distribution, and for making 70 miles more of canal, were framed; they were sanctioned in 1883 and the works have been resumed. Some details of these works and their estimated cost are given in the following tabular statements. Their effect will be to increase the irrigable area to 653 236 acres, which was about the area contemplated in 1867.

As to the financial condition, it seems due to several causes: to reducing the water rate from £0·5 to £0·15 per acre; and to contracting the irrigable area; but chiefly to the general policy of waiting for the natives. Apart from the liability of the lands to inundation, against which protection is required, these deltaic works are capable of high financial success, when carried out to full development.

The Orissa Coast Canal.—This canal was in progress of construction in 1881–1882.

Orissa Canals.—Works in 1882–83.

Canal.	Canal.	Distributaries.	Protected from Flood.	Under Command.	Provided with Distributaries.	Area Assessed.
	miles.	miles.	acres.	acres.	acres.	acres.
Kendrapara	39	33	129 421	101 110	87 300	56 066
Gobri	15	—	27 251	21 290	—	4 308
Pattamundi	47	—	65 600	51 250	—	12 094
Kendrapara Extension	15	—	8 960	7 000	—	—
Taldanda...	27	65	19 520	15 250	14 185	10 719
Machgong	19	113	44 928	71 600	35 100	34 012
High level, 3 ranges	64½	117	62 483	240 100	44 730	15 829
Total	226½	625	358 163	507 600	181 315	133 028

Orissa Canals.—Discharges of Rivers, in cubic feet per second, at their low stage.

Year and Month.	Mahanadi above Naraji.			Brahmini including Pattia.			Baitarni, including Barrah.		
	Maximum.	Minimum.	Average.	Maximum.	Mini mum.	Average.	Maximum.	Minimum.	Average.
1832									
April	1 063	750	902	1 541	62	252	820	73	266
May	1 212	854	1 039	1 160	1 531	1 875	2 369	158	698
June	1 005	736	888	?	988	21 166	7 178	148	1 534
July to October	Flood	—	—	Flood	—	—	Flood	—	
November	13 664	12 177	12 920	41 088	6 850	9 413	25 945	1 373	4 140
December...	12 295	7 377	9 533	1 557	1 749	1 937	2 040	1 026	1 430
1883									
January	5 882	3 309	5 236	1 563	1 032	1 257	1 689	855	1 172
February...	3 097	1 836	2 613	1 134	910	1 026	1 185	658	867
March	2 679	1 578	2 034	8 546	861	3 316	3 288	678	730

Orissa Canals.—Annual Progress of Works, Irrigation and Navigation, 1871 *to* 1883.

Year.	Average Supply.	Length of Canal open.			Area Commanded.	Areas.		Kharif. Irrigation.	Rainfall.	Navigation.
		For Irrigation and Navigation.	For Irrigation only.	Distributaries.		Irrigable.	Total Irrigated.			
	C. f. p.s.	Miles.	Miles.	Miles.	Acres.	Acres.	Acres.	Acres.	Feet.	Tonnage.
1871–72	—	—	—	—	—	—	11 652	—	—	—
1872–73	—	110·5	—	—	174 825	—	4 753	—	—	154 422
1873–74	—	—	—	—	—	—	12 571	9 104	3·4	—
1874–75	—	103	15	538	206 172	136 335	22 459	19 740	6·30	57 312
1875–76	—	103	15	551	—	136 335	18 409	13 991	5·83	60 574
1876–77	—	103	15	554	—	136 335	30 382	26 069	3·69	77 367
1877–78	—	109	66	587	—	155 835	98 495	95 088	3·99	105 527
1878–79	—	151	66	602	—	155 835	111 250	105 500	5·17	129 646
1879–80	—	158·5	66	609	501 370	155 835	109 038	105 186	5·07	110 185
1880–81	—	158·5	66	613†	—	182 380*	117 221	112 171	7·09	89 863
1881–82	1 154	158·5	66	626	—	182 380	132 278	126 611	4·73	143 522
1882–83	1 023	"	"	625	—	"	133 028	128 530	4·90	—

* The corresponding village channels were not made in this year.

Orissa Canals.—Annual Receipts and Expenses, 1871 *to* 1883.

Official Year.	Capital.		Water rate.	Navigation.	Miscellaneous.	Total Gross Revenue.	Maintenance.	Establishment.	Irrigation Establishment.	Navigation Establishment.	Tools, Plant, and Miscellaneous.	Total Charges.
	During Year.	Total Outlay.										
	£	£	£	£	£	£	£	£	£	£	£	£
1871–72	—	—	—	—	—	4 395	—	—	—	—	—	22 594
1872–73	—	—	—	—	—	3 662	16 388	2 655	4 138	615	3	23 800
1873–74	—	—	1 741	—	—	4 384	7 451	957	3 861	583	68	12 919
1874–75	—	—	2 038	2 141	669	4 849	11 755	2 010	3 502	569	1 807	19 643
1875–76	—	—	4 033	2 288	1 130	4 549	13 686	3 350	2 579	565	582	20 762
1876–77	—	—	4 038	3 384	945	7 456	14 049	3 164	2 501	584	1 169	21 466
1877–78	—	—	11 782	5 704	855	16 111	13 704	3 251	3 223	601	828	21 607
1878–79	—	—	11 642	9 808	1 370	18 200	14 711	3 907	2 760	745	1 786	23 909
1879–80	—	—	15 775	7 140	1 530	26 952	25 875	5 192	3 879	815	890	36 651
1880–81	—	—	17 805	8 400	1 600	26 476	19 955	4 590	3 881	750	1 304	30 481
1881–82	—	1 955 953	12 429	7 416	1 566	25 840	—	—	—	—	—	32 866
1882–83	36 496	1 992 449	18 033	—	—	32 001	—	—	—	—	—	34 154

The water rate was only £0·15 per acre from 1871 to 1881.

Orissa Canals.—Details of Cost of Works and Extensions proposed in 1882.

Detail.	Works Sanctioned.	Extension Contemplated	Total Estimated Cost.
	£	£	£
Headworks	460 542	—	460 542
Main canals	780 855	249 595	1 030 450
Distributaries	150 196	426 884	577 080
Drainage and Protection works...	110 276	349 551	459 827
Cadastral Survey and Boundary pillars	221 666	—	221 666
Total for Works	1 524 035	1 026 031	2 550 065
Establishment	413 274	256 508	669 782
Tools and Plant...	183 322	71 822	255 144
Total	2 120 631	1 354 360	3 474 499
Deduct Receipts on Capital Account	7 298	4 515	11 813
Total direct charges ...	2 113 333	1 349 846	3 463 179
Capitalised value of abated Revenue	9 199	9 532	18 731
Pension and Leave allowance ...	53 000	64 127	117 127
Loss on Exchange in England ...	29 409	—	29 409
Interest during Construction ...	1 041 923	1 662 342	2 704 265
Total indirect Charges ...	1 133 531	1 736 001	2 869 532
Total Cost	3 246 864	3 085 846	6 332 710

These works, with slight modification, were sanctioned as a whole by the Government of India on April 9th, 1883.

Orissa Canals. Extension of Irrigation sanctioned in 1883.

Works and Extensions.	Area Irrigable.	Canal	Distributaries.	Village Channels.
	Acres.	Miles.	Miles.	Miles.
Reduced works, officially sanctioned in 1876	224 308	224½	552	154
Actual works existing in 1882	192 965	224½	525	184
Proposed Extensions—				
Kendraparal Canal Distributaries	35 100	—	100	33
Do. Extension ...	7 000	—	20	7
Patamundi Canal	51 250	—	170	49
Gobri Canal	54 000	25	179	51
High-Level canal, range I. sec. 3	13 785	—	31	13
" " II. " 1	40 000	—	91	38
" " II. " 2	10 000	—	23	9
" " II. " 3	70 000	—	158	66
" " III.	57 500	—	130	54
Taldandah Canal Extension ...	60 028	24½	282	57
Machgong Canal Extension ...	61 608	20¾	198	58
By all Extension proposed	460 271	70¼	1 409	505
Works contemplated in 1882 ...	653 236	294¾	1 934	589
Works contemplated in 1867, for which the headworks were designed	662 000			

THE CANALS OF THE BOMBAY PRESIDENCY.

The Jámda Canal, in Kandeish, was commenced with an estimate of £10 000, and was opened in 1869.

The Krishna Canal has its headworks at Karwar, in Sattara, its estimate was £58 133; in 1872, 32 miles of canal were finished, and 2 038 acres irrigated, yielding a revenue of £955.

The Ahmadnagar Canal, estimated to cost £21 941, was opened before 1870.

The above comprise the whole of the canals of the Bombay Presidency in 1872. Information about them was then very scarce.

The accounts of the canals being mixed up with those of the tanks in official returns, there is some difficulty in separating them, as it is not always possible to discover whether prospectively the canals will be dependent mainly on storage works, tanks, and reservoirs, or mainly dependent on natural river supply. The irrigation now effected is of small extent.

Bombay Canals.—Irrigation in 1882–83.

Canal.	River of Supply.	District Irrigated.	Area Commanded.	Area Irrigable.	Area Irrigated.
			Acres.	Acres.	Acres.
Lower Pánjhra River works	Pánjhra	Khandesh	13 117	12 627	1 003
Jámda Canals	Girna	"	46 288	31 538	1 080
Kádva River works ...	Kádva	Násik	40 373	32 723	1 241
Pravara River works ...	Pravara	Ahmadnagar	119 689	99 931	2 741
Mutha Canals	Mutha	Puna	88 087	45 136	9 089
Revári Canal	Vásna	Sátára	3 812	3 624	519
Upper Mán River works ...	Mán	"	3 470	3 066	300
Chikhli Canal	Nandni	"	1 870	1 477	217
Krishna Canal	Krishna	"	27 407	25 533	3 023
		Total ...		...	19 213

Bombay Canals.—Reputed Average Discharges in cubic feet per second of the Streams of Supply.

Season	Month.	Pánjhra.		Girna.		Pravara.		Vásna.	Mán.	Mándni.	Krishna.
		Max.	Min.	Max.	Min.	Max.	Min.	Average.	Average.	Average.	Average.
Hot Season.	February	24	4	203	17	79	13	5	2	5	91
	March	46	3	161	6	53	10	4	2	3	51
	April	9	2	113	2	43	12	1	1	½	54
	May...	8	2	88	1	39	4	5	16	133	300
Mansún.	June	—	—	—	—	—	—	63	46	300	300
	July...	—	—	—	—	—	—	252	20	300	300
	August	—	—	—	—	—	—	115	14	141	300
	September	—	—	—	—	—	—	124	66	300	300
Cold Season.	October	—	—	382	62	113	100	49	29	79	291
	November	45	10	382	60	113	54	20	12	48	300
	December	40	6	382	51	113	29	26	8	18	265
	January	27	5	382	28	95	20	7	3	8	120

The discharges of the Kádva, Mútha, and Kalála are not available in any such form.

Bombay Canals.—Revenue Account for 1882–83

Canal.	Expenditure to end of 1882–83.	Revenue of Year 1882–83. Gross.	Revenue of Year 1882–83. Working Expenses.	Revenue of Year 1882–83. Net.	First Year of Irrigation.	Attached Reservoirs Existing or Proposed.
	£	£	£	£		
Panjhra works	43 116	745	399	346	1866?	Mukti, completed.
Jámda Canals	100 536	521	1 188	def.	1866?	Chaukapur, proposed.
Kadva Canals	40 735	698	593	105	1869–74	Wágһád, being made.
Pravara (Ojhar)	31 102	244	518	def.	1876	Maladevi, proposed.
„ (Lakh)	36 237	151	331	def.	1869	„ „
Mutha Canals	588 344	14 706	6 177	8 529	unknown	Mutha, completed.
Revári Canals	5 102	170	195	def.	„	Sonekeh, proposed.
Mán works	34 608	83	203	def.	„	Pingli, completed.
Chikhli Canal	5 742	83	117	def.	„	Pan Newri, proposed.
Krishna Canal	81 566	2 053	1 415	637	1870?	Kasand Tarla, proposed.
Total	967 088	19 454	11 136	8 318		

The so-called Yerla canals are admittedly supplied solely from the Nehr tank, hence they are channels of storage works. The Kalala Canal, in Dharwar, is apparently awaiting its tank, and is perhaps in the same category.

The nature of the remaining nine canals may be judged by the hot weather discharges of their streams of supply. Most of these will probably be converted into channels from storage works, which should have been originally made at the same time. Their names are given attached to the revenue account of the works for 1882–83.

The Mukti reservoir is evidently merely a subsidiary or supplementary work; the Pingti tank seems of doubtful nature, also the Mutha tank.

THE CANALS OF THE MADRAS PRESIDENCY.

The Tumbaddra Canals.—The principal headworks of these canals consist of a weir across the rocky bed of the Tumbaddra at Sunkesala, 4 500 feet in length of clear overfall; the section varies, but is everywhere 8 feet broad at the top, the alternate stones of the coping being 1 foot thick, 8 feet long, and weighing each $1\frac{1}{2}$ tons. The mortar used is Karnul kankar, except for the coping which is in Portland cement. The height varies from 6 to 26, averaging 18 feet; and the highest registered flood rose $7\frac{1}{2}$ feet over the crest.

The main features of the canal are as follows:—The first 75 miles are designed to carry 3 000 cubic feet per second at the head, and, after parting with one-fourth of this for irrigation, to convey the remainder through the Metakandal watershed cutting at its other extremity. There 1912·5 cubic feet per second can be discharged into the Kali, and 337·5 carried down the continuation of the canal. Of the 1912·5, 750 are taken up at a fresh off-take at Jatur, and 375 at Rajoli, leaving 750 for irrigation below Kadapa.

The minimum section of the canal in the first 75 miles has a bed-width of 90 feet, with 2 to 1 side slopes. For the first 45 miles, the fall is adapted to a maximum depth of water of 8 feet, below the 45th to one of 9 feet. The gradient of the canal is generally from 0·3 to 0·5 feet per mile, but in one or two deep cuttings 1·5 feet. Below the 75th mile, the natural watercourses of the Kali and the Kunder become the main channel of supply. The 1st branch channel forms the canal from the 75th to the 95th mile; it has a head sluice and lock at Lockinsula, from which it is an irrigating channel 6 feet deep for the first 6 miles, with a flow of 337·5 cubic feet per second. Below that it is a still-water canal, of a minimum depth of 5 feet, and a bottom breadth of 45 feet, having a fall of 180 feet, overcome by 7 double and 5 single locks, of chambers 120 × 20; the greatest fall of a double lock being 21, and of a single one, 13 feet. The 2nd branch channel forms the canal, from the Jatur Weir at the 95th mile, to the 146th mile; it is adapted for a depth of 6 feet of water down to the 1st drop lock at the 118th mile. The weir is 6 feet broad at the top, on foundations of shale; it has head sluices, scouring sluices, and an entrance lock, with a water

cushion below the fall. Irrigation ceases at the 130th mile. From the 118th to the 146th mile the canal consists of level reaches with 5 feet depth of water; having 17 locks to overcome a fall of 188 feet, the maximum fall in any single lock being 14 feet. The bed-width throughout is 50 feet. The 3rd branch channel, from the Rajoli Weir at the 146¼th to the 180th mile, has also a bed-width of 50 feet, and with 5 feet of water will discharge 375 cubic feet per second. The Rajoli weir is made of limestone rubble, and built on rock; its top thickness is 5 feet, its front batters 1 in 2, and its lower face is vertical.

Across the Penner at Adanimayapilli are the headworks and off-take of the projected continuation of the canal to Nellor; the weir is mostly founded on wells in sand; 8 miles of this canal are open, and supply 375 cubic feet per second for irrigation.

The Hindri aqueduct, carrying the canal, 90 feet broad and 8 feet deep, at an elevation of 32 feet over the Hindri by fourteen 40-feet arches, is a large work. No modules are used on these canals. The ordinary hand sluices are of two sizes, one 5 feet broad, and of 3·75 feet lift, the other 1·5 feet wide, and 1 foot lift; each is worked by turning round a vertical screw that lifts a cross head, to which the cast-iron shutter hangs; each turn of the screw raising the shutter 1 inch and being easily worked in cast-iron grooves by one man against an average head of water of 6 feet.

The cost of the canal for the first 75 miles averaged £8 000 a mile, and for the rest of its course £2 900 a mile.

This Tumbaddra project was first brought forward by Colonel Haviland; it was carried out by the Madras Irrigation Company, having been commenced under the auspices of Lord Derby, and sanctioned in 1861, the estimate by Government officials amounting to one million sterling: the headworks were opened, and water admitted, in 1864: as the works could not be completed within the estimate, a loan of £600 000 was made to the company by the Government in 1866, under the condition that these works should be completed in July, 1871. They were completed by that date: 216 miles of canals and 377 miles of distributaries, commanding 91 567 acres, being opened. In 1872–73, the acreage commanded was 156 570 acres, being in excess of that necessary, when taken up, to repay the 5 per cent. interest, namely 130 000 acres. The actual acreage irrigated, and returns up to the present time stand thus:—

In 1870–71	... 1 478 acres, yielding			£897
„ 1871–72	... 9 980	„	„	3 541
„ 1872–73	... 9 505	„	„	5 020
„ 1873–74	...19 791	„	„	8 161

The small acreage in 1870–71 was due to the damage to the canal caused by unprecedented storms; and for which insufficient escape had been provided. In 1871 this was repaired, and the canal improved, and in 1872 water was again admitted throughout the whole length of the canal, to a depth of from 2 to 5 feet. In 1873–74 the canal carried 375 cubic feet per second, having a depth of 4 feet of water throughout.

The eventual irrigating power of this series of canals is assumed to be limited to 250 300 acres of rice cultivation, at a duty of 66 acres to 1 cubic foot per second in places where the waste water is lost, and of 50 where it is again taken up by the canal; this is, however, on the supposition that these canals remain dependent on the rainy season supplies of the Tumbaddra; should storage reservoirs be employed, as intended, to render the canals perennial, this acreage may be doubled.

On July 6th, 1882, these canals were purchased for the sum of £1 763 500, and transferred from the Madras Irrigation and Canal Company to the Government of Madras.

On July 18th, 1882, a flood breached the Sunkesala dam for 300 feet, and the north flood bank and temporary dam were carried away by a high freshet in November, 1882. Navigation and irrigation for the year was stopped; though unusually heavy local rain saved the crops from ruin.

The water rates were very largely reduced on transfer to Government; and to holders of 50 acres in block, water is supplied free for the first five years, and at half-rates for the next five years. The extension of the distributaries was commenced, and will be completed probably in three years.

The area irrigated during 1882–83 was 15 010 acres, and the revenue realised £5 090. It is hoped that in future the revenue will repay the cost of maintenance.

The Deltaic Works of Southern India.

The Kávari Deltaic Works.—The river at the delta-head is 4 400 feet wide, with a depth in high flood of 12 feet, and a

maximum flood discharge of 284 000 cubic feet per second. The river and its tributaries are fed by both mansuns, so that its supply is abundant for nine months in the year. It commences in the middle of June; a fuller stage commences in the middle of July and lasts till the end of August; in September it is very low, but there is then local rain; in October and November there are small freshets; in the middle of November the supply culminates in very heavy floods, after which it diminishes gradually until March. The three months from March to June are the dry-stage season.

The earliest Deltaic Irrigation Works must have here existed in some rough form for ages, certainly long before any permanent masonry weir or works in stone were ever made to regulate them in any way. The local conditions, so favourable to irrigation, both as regards natural disposition of the land and deltaic river channels and with respect to continuity of water-supply and local rainfall, exist nowhere else in India on so large a scale with equal advantages.

In this remote period of rough irrigation, the deltaic course of the Kavari, below the Srinagram fork, was that of a large, well-defined deep river, running in *an elevated ridge*, and discharging into the sea; while the Kalarun, or second branch of the fork (now the actual river), was the drainage or overflow channel of the delta, and was subsidiary. The local origin of irrigation consisted in the Kavari bursting through and overflowing its banks, thus giving flood irrigation in the delta in high-flood season, and forming high-level drainage channels as well. That is to say, natural causes formed both off-takes and channels of supply long before the Telingi rajas made any anicuts there. The natural cause was the natural tendency of an elevated deltaic river, of tortuous course, to silt up and flood its sloping banks: the result was flood irrigation of a fitful, uncontrolled sort.

The next step was doubtless due to human ingenuity or love of improvement. Brushwood, reeds, or matting and clay, aided by a small amount of excavation, were means adopted to improve the breaches into manageable off-takes; while the amount of cutting must have been very small in slightly deepening these short breaches, or natural off-takes. The results were at first, flood irrigation in parts of the delta from November to February,

that is for four months. Such irrigation was then amply sufficient for the needs of the cultivation, and may have lasted in this form and way for many centuries, as well-controlled flood-season irrigation.

The third era was the result of natural causes; the silting up of the deltaic Kavari had progressed to such an extent that its flood-season discharge (three to four months) failed to maintain sufficient waterway section to enable any dry-season discharge at all to pass direct into the sea. This change was a turning point; from this time the deltaic Kavari carried less water, while the supply to the Kalarun increased. In other words the Kalarun ceased to be a subsidiary deltaic branch; its course being more direct and its fall greater, it could discharge more rapidly the water that the deltaic Kavari failed to pass into the sea; and from the time that the Kalarun began to do so, there was a change of fluvial regimen, also a change in the conditions of flood irrigation.

The deltaic Kavari carrying less water from the fork downwards, and having a diminished declivity, had become comparatively mild in its lowest reaches; the crops were there less liable to damage from unbridled flood; the amount of water for the crops of a comparatively small area was enough on the whole; but as the Kavari at its lower end had at this period a reverse slope, or perhaps a dead level, for several miles in the lower reaches, the cropped area formerly irrigated from these reaches now received sufficient water.

The cultivators in this part of the delta hence adopted the remedy naturally applied to a mild, shallow river channel: they annually made temporary matwork or brushwood dams, or weirs, filled with earth or clay; these elevate the water-levels slightly, and more water is drawn off for immediate wants. But the remedy produced permanent ill-effect in increasing the silting-up of the bed of the deltaic Kavari. Eventually some unusual flood in the main river rushed down, dividing itself along the Kalarun and the Kavari; the latter from its advanced, silted condition being unable to dispose of its share in simple flow, formed a breach at the narrow neck of the delta, only 17 miles from the delta-head; thus forming a permanent large spill into the Kalarun. The whole of the irrigation on the remaining 90 miles of the deltaic Kavari being now threatened with extinction, the

cultivators decide that their only safeguard consists in closing this large breach by a dam or anicut, thus stopping any future permanent outflow into the Kalarun from the upper reaches, beyond that of a controlled flood escape. They hence apply to the despotic rajah for orders to execute this intention.

The Telingi Anicut resulting marks the fourth era in the fluvial regimen ; the time elapsing between the first era and the fourth, when a large rough stone weir was first made, may have been twelve centuries or more, it may possibly have been as short as six centuries, but certainly not less. There is, however, yet another alternative theory generally believed, but, according to this author, quite untenable. It is that the Telingis entering Tanjor after conquest, instituted irrigation there as a novelty, and ordered the anicut to be made to close a natural old channel from the Kávari to the Kalarun, so as to obtain it. These Telingis came from the neighbourhood of the Godavari and Kistna, in the second century ; and ancient anicuts on rivers dating from before that time, did not exist there, as far as human knowledge, historical or archæological, can direct; not only that, but the conditions for agriculture and irrigation are generally there far less favourable than those of Tanjor, both as regards the single mansun rainfall, and the fitful nature of rivers in flood, and the convenience of periodicity of the Tanjor rainfall supplying the hiatus in continuity of river supply.

In the northern provinces, storage was the natural mode of supporting irrigation, not river-weirs. It is also notorious that the anicut tanks had no flood escape-weirs; hence the invading Telingis probably knew nothing about anicuts until they had arrived in Tanjor. Even if we grant that they had not remained long near the Godavari, but had been driven out of Northern India shortly before, they probably did not bring thence any knowledge of stone anicuts. For these Hindus came from Audh, and Upper Bengal and Bahar, Gour and Gayah, where the rainfall was ample for the crops usually grown at that epoch and stone anicuts were not needed ; irrigation from shallow wells was there usual.

Setting aside this alternative theory, we will assume the more rational one that the Telingis caused the large anicut to be built of stone to meet local demands dependent on a whole

series of pre-existing local conditions, as before explained. The great rajah would even then get the traditional credit for everything, although he may have merely given the *fiat* or *huhm*. This principle still exists among the bureaucratic Anglo-Indian officials, and among the plutocratic engineering managers of Westminster, to the present day: both types induce people to term them eminent engineers, although they do not engineer; so did these rajahs of Tanjor and Trichinapalli; similarly also they drew large profits on account of presumed eminence.

It is difficult to assign any date to the Srinagram anicut. Some clever archæologist may yet do it; but this to be correct would be based on the actual stones, as well as on ancient inscriptions; either separately would form insufficient evidence of date. Any belief in its extreme antiquity is annulled by evidence of comparative lateness of the causes leading to its construction.

There is not any useful historical detailed record of the extent or mode of irrigation under the control of the Telingi anicut.

In 1804, when Tanjor was ceded to the British, the Grand Anicut of Srinagram was a continuous mass of rough stone or causeway, 1 080 feet long, 40 to 60 feet wide, and 15 to 18 feet in depth; rather irregular and of serpentine alignment. Its crest is (now?) about 7 feet above the bed of the Kávari. Later examination showed that the exterior facing alone was formed of rough granite set in mortar, that much of the interior consisted of granite set in mud, and that the whole had a mud core. The amount of irrigation then existing must have been large, for even as late as 1825, before any English weirs were made, 505 000 acres were irrigated from the Kávari branch, and 165 000 from the Kalarun branch. Probably, even long before 1804, a new dam of earth and grass, &c., was made annually across the Kalarun at the delta-head to force a supply into the Kávari; for it was a constant practice between 1813 and 1822.

But, however rough and clumsy the whole mode, the Tanjor natives had in full action extensive and nearly fully developed works of deltaic irrigation, of which the chief part was not the Grand Anicut, but consisted in a vast extent of channels of irrigation developed out of natural overflow channels on the soundest principles of economy and utility.

This system has been the parent of all subsequent deltaic

irrigation in India; even some of its incidental defects, such as sand cores, miserably shallow foundations, packed drystone talus of moderate batter, requiring annual renewal, have been servilely perpetuated in other works, without much exercise of judgment as to suitability or improvement. In fact, this was carried so far as to treat ignorance of Tanjor conventionalities as ignorance of hydraulics; in the same way as opposition to, or neglect of, Westminster routine is now treated in England as engineering ignorance. More remarkable was the subsequent claim of the imitators to the deltaic irrigation of Tanjor, as their own doing; an attempt that eventually was overruled.

The English Anicut of Cotton and Sim marks the fifth era in the fluvial regimen. Considering it as a whole, which it now is, it was built between 1835 and 1845. Though these great men apparently were the originators of permanent deltaic weirs as headworks, their first efforts were imitative, then tentative, and subjected to failure; but they were officials with plenty of time for maturing and improving their tentative work. The causes leading to their intervention in Tanjor were these.

In 1804, Captain Caldwell, of the Engineers, had noticed the progressive diversion of the supply to the Kavari into the Kalarun at the delta-head, and foretold the annihilation of the deltaic Kavari as an irrigating stream, if some remedial measures were not taken. This meant the ruin of Tanjor. Besides the progressive continued silting-up of the bed of the Kavari branch, breaches occurred in flood at parts of its low embankments, and silt was carried over large tracts of land, thus spoiling it. In 1806, Captain Caldwell raised the Telingi anicut by a few feet, also much of the embankments. These measures for holding more water in the Kavari channel and protecting the land were continued until about 1822; but they were unequal to Nature in the contest, and it became evident that a serious catastrophe would eventually occur, if something different were not done.

In 1828, Captain Cotton examined the condition of the Kavari, and in 1829 Major Sim, of the Engineers, proposed scouring sluices from the Kavari into the Kalarun to remove the silt from the bed of the former. His proposals were carried out about the following dates:—

Date.	Sluices.	Place.	Cost.
			£
Dec. 1829 ...	10 vents 4′ × 3′	in the Telingi anicut ...	1715
Jan. 1831 ...	12 ,, 4′ × 3′	at Vadavagudi	2383
Apr. 1832 ...	,,	at Permakovil	1107
Feb. 1833 ...	20 ,, 12′ × 5′	near Delta-head	2396
and 1834 ...	a waste weir attached to them.		—

These were exceedingly effective in reducing the level of the bed of the Kavari, and relieved all immediate danger of breaches in the embankments.

In 1834, Captain Cotton's proposals were made, in 1835 they were sanctioned and his works commenced. They consisted originally in a permanent weir at the delta-head, but over the Kalarun branch only, to replace the old annual mud weir, and to force water into the Kavari. The weir was in 1845 prolonged at a lower level across the Kavari branch. His expenditure was thus :—

	£	
1835 ...	9838 ...	Original works: weir, lock, and sluices.
1836 ...	1486 ...	Rebuilding breaches made in it.
1837 ...	1061 ...	Subsequent improvements, and wall protecting the island at the fork.
1838 ...	1048 ...	
1839 ...	1876 ...	
1840 ...	113 ...	
1843 ...	2494 ...	Extension of works, and lowering the crest.
1845 ...	195	
1845 ...	7274 ...	Extension of weir across the Kávari branch to a low level, by Major Sim.
1846 ...	2297 ...	Enlargement of under-sluices, Kalarun branch, and extending the apron.
	27682	

The complete weir, or English anicut, across the delta-head was then completed so as to adjust the ordinary flow in the Kavari and Kalarun branches as required, to carry off excess of water into the Kalarun, and to clear accumulations of silt into it from above the river. Some alterations and repairs effected in 1858 and 1871 were comparatively very small. The following is a brief description of the existing weir in its present condition. In the portion across the Kalarun branch, the foundations consist of two rows of wells, 9 feet deep, and 4½ feet external

diameter, filled with concrete; above these is brickwork 6 feet broad and 3 feet high to bed-level. The body-wall resting on this is 7 feet high in the northern section, and 5 feet 4 inches to 5 feet 10 inches high in the southern section. Below is a masonry apron 2 feet thick, and 31 to 40 feet broad, supported by a retaining wall 3 feet high, resting on wells 6 feet deep. Below this is a rough stone apron 12 feet broad.

On the north bank are the off-takes of the Iyen and Peruvelli channels; on the south end of it is a masonry wall 14 feet high running round the point of the island of Srinagram, or delta-head, and continuing till it joins the portion of weir crossing the Kávari branch.

The portion across the Kávari consists simply of a flooring 3 feet thick, of which the upper part is in cut stone, on the level of the bed of the river, resting on two rows of wells 6 feet deep and of 4½ feet external diameter, filled with concrete. The up-stream side is protected by a rooge stone apron 9 feet broad, and the down-stream side by one 21 feet broad. There is also a row of wells 12 feet from the flooring, intended to carry the rear retaining wall of a bridge, whose foundations alone have been built on this portion. Over the Kalarun section there is a narrow bridge, 6 feet wide, of 50 arches.

The total length of the weir is as follows:—

		Feet.	Feet.
Over the Kalarun—	North branch.—Sluices ...	48	393
	Weir ...	345	
	Island	...	660
	South branch.—Sluices ...	111	1 736
	Weir ...	1 625	
Delta-head.—Masonry connecting wall round delta-head		not given.	
Over the Kavari.—Weir flooring between wings		...	1 950
Length, excluding delta-head ...		...	4 739

Proceeding to other works, below the delta-head, executed about this early period, 1835 to 1846, and in the succeeding twenty years till 1866, when official accounts commence in detail, the regulating and escape works were as follow:—

	£
1830...Ten sluices in the Telingi anicut	—
1834...Sluice and passage from the Kávari to the Vennar	—
1834...Improvement of the Vetar channel	2 306
1839...Koviladi escape-weir	—
1839...Improvements and bridge over the Telingi anicut	851
1851...Kávari and Vennar regulators	4 992

The following minor miscellaneous works were also carried out in the delta between 1858 and 1857:—

	£
1850...Improvement of the Valavanar	724
„ ...Drainage channels...	474
„ ...Escape-weir and bridge, Govinden Kalagam ...	332
1851...Improvements of channels and their off-takes ...	1 284
1852...Improvements of channels and embankments ...	3 195
1856...Reconstruction of Adapar weir	336
„ ...Dam across the Vennar	263
„ ...Rendering the Muniyar navigable	3 354
„ ...Tulnoyer Kottagam Tank distribution	2 652
„ ...Improvements of channels	2 022
	14 636

The above were all works charged to capital account. From the foregoing it appears that the distribution effected under native rule was generally allowed to remain in its pristine state, apart from repairs, for a long time after the English headworks were made. The following are the details of receipts during this period:—

Year.	Area Irrigated.	Revenue Receipts.	Saved in new Maintenance.	Total.	Total Revenue of Tanjor District.
	Acres.	£	£	£	£
1830	546 820	—	—	—	388 751
1837–38	668 386	17 949	14 030	31 979	368 986
1846–47	704 591	50 943	14 030	64 973	422 381
1856–57	709 305	37 260	14 030	51 290	420 378
1866–67	741 454	55 756	14 030	69 786	410 030

These results prove that at least one-fourth more irrigation recovered was due directly to the headworks, besides the salvage

of the whole previous irrigation. The success of this achievment of Colonels Sim and Cotton led to the later undertakings in the Godavari, Kistna, and Penner deltas, as well as others.

Modern and recent Improvements.—These mark a new stage in the Kavari deltaic works, beginning about 1870, or certainly after 1867. Their object was a regulated and improved distribution, apportioning due supply to all the channels, and the exclusion of injurious floods.

The location of the rivers, canals, and channels of distribution must be mentioned before referring to works connected with them. It is naturally difficult for anyone that has not resided long in that part of the country to describe local matters accurately, even with the aid of maps and such knowledge as official and other records give; and it is impossible to avoid error entirely. The half-dozen Kavaris, the difficulties about local names, and those due to native technical terms applied to things widely different in point of technical effect, have all been used as scares against intruders in these mysteries of defective distribution and river control bequeathed by the natives to local Anglo-Indian officials. Some error is hence pardonable in any attempt at brevity, and this will not necessarily invalidate general remarks and technical deductions.

The total irrigated area of the delta amounts to 822 000 acres, and this is fully supplied at the rate of 1 cubic foot per second to $66\frac{2}{3}$ acres by a supply of 12 330 cubic feet per second passing over the English weir at the delta-head, with a depth of 5·7 feet on its section across the Kavari.

The main channels of supply are the Kavari itself and the Vennar, which branches off southwards from it at a point nearly $14\frac{1}{2}$ miles from the delta-head, and about $2\frac{1}{2}$ miles above the Telingi anicut, or principal spill into the Kalarun.

The accompanying tabular list of other deltaic channels, with their approximate lengths, &c., will help to explain matters, although details of irrigation are not available.

The irrigated delta may be roughly divided into three parts. A strip between the Kalerun and the Kavari, varying from 0 to 16 miles in width; the central part, between the Kavari and the Vennar, a triangle about 68 miles long and 40 broad; and the southern part south of the Vennar, which above the city

of Tanjor is narrow, but below it is a triangle about 35 miles long and 35 broad.

The proportions of water-supply and irrigation in the gross are thus:—

	Acres.	Percentage of Supply. In Low Flood.	Percentage of Supply. In High Flood.
Under the Kávari ...	429 000 ...	70 ...	78
Under the Vennar ...	393 000 ...	30 ...	22
Total ...	822 000	100	100

At present, when there is a high flood, corresponding to a depth of 10·5 feet on the gauge at the English weir its disposal, after entering the Kavari, is effected by passing 39 per cent. of it over the Telingi anicut into the Kalarun, while 39 per cent. continues along the Kavari, and the remainder is taken by the Vennar. Floods of gauge-readings 11·3, 11·9, 12·5, and 13·3 feet have occurred; in the last case (in 1858) the land was thoroughly inundated.

It may be observed that all flood in excess of a fixed supply cannot be passed down the Kalarun at the English weir at the delta-head, for fear of damaging a weir on it much lower down, called the Lower Kalarun Weir; also because the waterway of the Kalarun is irregular and ill-suited to rapid drainage.

The capability of dealing with such an extreme flood as that of 1858, giving about 284 000 cubic feet per second into the deltaic Kavari at the English weir, without damage to land or works, is hence one of the objects of modern regulation. Also it appears that, even with ordinary conditions, much damage is done: for, from 1860 to 1870 the annual remissions of revenue, due to excess and want of water, were £7 068, of which nearly two-thirds were for lands watered from the Vennar, the rest from the Kavari. (The Vennar appears unprovided with escapes.) So that the whole arrangement of distribution requires regulating.

As to the regulating works already made, the old works are: the escape made by Colonel Sim in 1834, at 3 miles from the delta-head; the Koviladi escape, built in 1839, at 19½ miles from the delta-head; the Kavari-Vennar regulators, built in 1851, at a cost of £4 992, to regulate the apportionment of supply to these two rivers, at 14½ miles from the delta-head;

the Telingi anicut, at 17 miles from the delta-head; also the Kuchamangalam anicut, an old native work, 8 miles below the head of the Vennar. These have proved inadequate.

The more modern works are :—

Date.		Dist. from Delta-head. Miles.	Cost. £
Unknown ...	The Kodamurte regulators ...	$26\frac{3}{4}$; dam of 442′ ..	9 945
Unknown ...	The Vadavagudi escape ...	$32\frac{3}{4}$; weir of 109′ ...	—
1868 ...	The Arasillar regulators ...	$46\frac{3}{4}$; dam of 210′ ...	1 606
1868 ...	The Verasholen regulators ...	$60\frac{1}{3}$; dam of 133′ ...	1 178
1870 ...	Vetar regulator sluices ...	$32\frac{1}{3}$; 47 vents of 10′ ...	20 773
„ ...	Pamaniar and Korayar ...	$57\frac{1}{4}$; 27 „ 10′ ...	
„ ...	Pandoviar do. ...	$64\frac{1}{2}$; 16 „ 10′ ...	
„ ...	Villayar do. ...	$65\frac{3}{4}$; 14 „ 10′ ...	
„ ...	Surplus dam on Anunda ...	... ...	745
1877 ...	Tirumalrajen regulator sluices	$43\frac{1}{4}$; 26 „ 10′ ...	8 188

In 1880 it was proposed to construct a reservoir on the Bhaváni, a tributary river, to hold 27 000 million cubic feet, and to occupy 30 square miles, with a canal 100 miles long, which would supply 50 000 million cubic feet of water annually to the deltaic lands.

In March, 1882, an expenditure of £68 800 was sanctioned for new headworks to the Kávari and the Vennar, as well as other regulators and alterations; whence it appears that the works of 1868 to 1877 were insufficient by themselves; and that the perfect control of the distribution will not be effected before 1887.

When finished, the Kávari deltaic works will have become English throughout in every respect.

Kávari Deltaic Works.—Detail of Irrigation.

Chief Deltaic Channels.	Distance of off-take from Delta-head.	Approx. Length.	Irrigation.	Proportion of Supply taken from the parent stream at the off-take.
	Miles.	Miles.	Acres.	Per Cent.
North from the Kávari.				
Munniyar	33·19	50·	34 527	—
Palavar	44·76	40·	19 501	—
Vikramanar	69·50	10·	12 524	—
South from the Kávari.				
Kodamurti	26·77	47·40	114 889	—
Arasillar	46·66	28·	80 102	—
Verasholen	60·50	25·	55 125	—
North from the Vennar.				
Pillai Voikal	22·12	10·	8 136	—
Vetar	32·57	57·	94 541	37
Shembaga	36·50	14·	—	—
Ragunada	41·50	13·	—	—
Pandalliar	64·	20·	21 365	56
Vellayar	65·	20·	35 713	37
South from the Vennar.				
Anunda	22·12	16·	3 865	—
Vadavar	32·00	42·	13 014	—
Pamaniar	57·20	30·	33 546	16
Korayar	58·20	40·	113 216	34
Minor Channels.				
From the Kávari group	—	—	82 489	—
From the Vennar group	—	—	44 876	—
Irrigated by surplus ...	—	—	54 619	—

Kávari Deltaic Works.—Revenue Account and Yearly Irrigation.

Official Year.	Capital Outlay.		Gross Direct Receipts.	Share of Enhanced Revenue.	Working Expenses.	Simple Interest.	Net Profits.	Acres irrigated.
	During the Year.	Total.						
	£	£	£	£	£	£	£	
To end of 1866–67	—	60 871	127	1 439 795	561 948	52 939	825 035	—
For 1867–68	3 846	64 717	244	77 701	11 665	2 702	63 578	748 124
„ 1868–69	7 658	72 375	173	80 057	11 604	2 875	65 751	753 903
„ 1869–70	356	72 731	157	83 359	11 088	3 221	69 207	762 936
„ 1870–71	5 282	78 013	112	84 734	11 232	3 237	70 377	768 974
„ 1871–72	12 930	90 943	42	84 375	8 945	3 431	72 041	769 409
„ 1872–73	6 017	96 960	10	87 465	9 761	3 850	73 864	773 217
„ 1873–74	5 994	102 954	67	86 752	9 037	4 076	73 706	767 685
„ 1874–75	3 081	106 035	392	92 463	16 289	4 272	72 294	789 632
„ 1875–76	3 165	109 200	41	89 077	15 762	4 394	68 962	788 612
„ 1876–77	(—82)	109 118	437	82 366	17 424	4 471	60 908	772 639
„ 1877–78	1 192	110 310	303	87 740	17 869	4 491	65 683	794 722
„ 1878–79	1 132	111 442	486	98 802	16 731	4 563	77 994	805 033
„ 1879–80	3 984	115 426	348	104 449	14 882	4 648	85 267	814 366
„ 1880–81	(—3 499)	111 927	513	88 870	21 858	4 653	62 873	812 078
„ 1881–82	—	111 927	1 097	97 374	19 904	4 069	74 498	unkn.
Liability after 1881–82	—	—	4 549	2 765 379	775 999	111 892	1 882 037	

The Godavari Deltaic Works.—The Godavari, at its delta-head, has a maximum flood discharge of 1 210 000 cubic feet per second; its delta commences about 40 miles from the sea, and has an area of about 2 020 square miles. About the end of last century, Michael Topping reported to the Government his proposal to irrigate the delta. In 1833–34 a severe famine in the Rajahmandri districts occurred, and the population was much reduced by it. The special commissioner deputed to make inquiries was Sir Henry Montgomery, who had had experience in irrigation matters in Tanjor. He recommended, in 1844, the thorough examination of the delta with the view of reviving the scheme. In 1845, Major Cotton proposed the construction of a dam at the delta-head, and the construction of channels to command an irrigable area of 615 000 acres. It appears that at that time the cultivators had already utilised some natural channels to irrigate 81 600 acres for fifty days in the year. The first estimate of Major Cotton, sanctioned in December, 1846, amounted to £47 557, of which about three-fourths was for the dam, its locks and sluices; and the works began in 1847. In September, 1848, an augmented estimate was sanctioned, including other sluices, which brought the whole to £61 467. A third estimate, amounting in all to £91 121 for past and future work, was drawn up by a special committee, and was sanctioned by the Court of Directors in July, 1849. During construction the works were breached by severe floods, and extensions of works were considered necessary. Two additional sums, £2 571 and £6 574, were sanctioned in 1851.

In April, 1852, the dam was completed in accordance with the design; but it was not sufficiently high to afford enough water at a convenient level; hence £2 217 were then spent in raising the crest 2 feet by means of iron posts and shutters. Apparently this condition of the dam remained for ten years.

In 1861–62 the general raising of the whole dam by 2 feet, making its wall 14 feet high, was effected on an estimate of £28 254; this was afterwards increased to £30 000. In 1867 the total expenditure on original works amounted to £126 379, a sum less than the sanctioned £130 977. In 1882 the sum of £6 461 was spent on under-sluices, the whole being then brought up to £132 840 as cost of headworks.

The headworks at Dauleshwaram consist of a dam or weir

across the river, hereabout 18 000 feet wide, and three sets of sluices and locks, from which the three main channels irrigating the eastern, the central, and the western deltaic regions are supplied. The river width is broken by islands to a total length of 4 500 feet, on which earthen embankments connect the portions of masonry weir. There are also flanking embankments raising the earthwork to 7 000 feet in length, as well as wing walls 2 500 feet long in all; the masonry weir itself consists of four portions, altogether 11 946 feet long.

The first or eastern portion is 4 940 feet long, adjoining the off-take for the eastern delta; it is founded on shafts 6 feet in diameter, sunk 6 feet; it is 19 feet thick, consisting of a core of rock sand, faced by a curtain wall 7 feet high, and 4 feet thick at the base, having also a masonry counter-arched fall 28 feet broad and 4 feet thick; the wasteboard of cramped stone is 4 feet thick and 19 feet broad, the massive stone apron 80 feet broad; on both flanks are masonry wing walls and revetments; on the east flank a lock, under-sluices for silt, and the head-sluices for the eastern main canal. Beyond the first island, Pichaka Lanka, is the second portion of the weir, 2 860 feet long; this has a core of rough stone, and extends to Babber Lanka, the second island, where are the head-sluices of the central main canal. The third portion of the masonry weir is 1 548 feet long, extending to the third island, Maddur Lanka. The fourth or western portion of the weir is 2 598 feet long, and has on its western flank the head-sluices of the western main canal, a lock and under-sluices.

The three sets of head-sluices have the following dimensions: eastern, 13 vents of 6×8 feet; central, 15 vents of $6 \times 8\frac{1}{2}$ feet; western, 15 vents $7\frac{1}{2}$ feet high, and of width varying from $5\frac{1}{2}$ to 6 feet. The total sections are thus, 624 square feet, 765, and 654; or, altogether, 2 043 square feet.

Ordinarily, the river begins to rise about the middle of June, and remains in flood through July, August, and September; it falls gradually throughout October, and until December, which is the end of the cultivating season. The delta is fully supplied when the water is 3 feet above the crest of the weir.

The development of the canals in the three deltas did not follow any general plan; but the dates of successive estimates sanctioned will indicate the gradual mode in which it was effected. The annual expenditure is given in the table.

In the eastern delta, November, 1849, £5 316; February, 1852, £17 636; November, 1853, £4 174 for distributaries; March, 1853, £4 823; June, 1854, £1 119; November, 1856, £11 734, but this was for a navigable canal for communication with the port of Kokanada; in 1864, £8 400, which, in September, 1868, was augmented to £13 120; May, 1871, £94 540, which included £46 940 for drainage; March, 1874, £23 320. The total completion estimated for works alone then amounted to £131 400, besides establishment and plant. In 1882 the total was £142 000 for works, and £70 838 for establishment and plant.

The mean supply to the eastern delta during the cultivating season—June to December—is 2 826 cubic feet per second, and this represents the carrying capacity of the eastern main canal; its distribution through the canals to the land is detailed in a subjoined table. The acreage was formerly 188 170 acres, but this is now reduced to 170 000.

In the central delta one main feeder as far as Ralli existed before the weir was made; the successive sanctioned expenditure on the canals of this area were thus:—November, 1849, £3 401; in February, 1852, £13 865, which, in May, 1853, was augmented to £16 894; July, 1853, £1 599; November, 1853, £5 840. In this year the works were twice greatly damaged by floods. In April, 1854, £1 545; April, 1855, £3 611. From this time until 1863 the expenditure was trivial; in 1863, £935; October, 1868, £2 142. In 1878 there was damage by flood; June, 1879, £1 285. The completion estimate of March, 1882, was for a total of £118 207, of which £92 000 was for works alone.

The carrying capacity of the main central canal is 1 745 cubic feet per second; the former extent of irrigation in the central delta was 95 000 acres; it will shortly be extended to 122 420 acres. The details of distribution through the canals, are given in the table following.

In the western delta there was irrigation from the Weyeru Channel before the weir was made. The successive expenditure on the canals afterwards was thus:—In 1851, £7 640; in 1853, £7 138; in 1854, £28 764 for the Ellor Canal, and £1 251 for drainage channels; also, in 1854, £11 320 for the Narsapur Canal; in 1857, £13 484 for a canal of which only part was in the western delta, valued at £4 500; in 1859, £5 391, and perhaps more; in 1862, £8 012; in 1867, £10 400. After 1867

the details appear to have taken the form of sanctioned completion estimates as totals. In 1869, £10 549 was sanctioned. The completion estimates sanctioned in August, 1871, gave a total for works of £130 464. The revised completion estimates of March, 1882, gave a total of £206 036, of which £153 000 was for works alone, apart from establishment and plant.

The extent of acreage irrigated in the western deltaic region was, in 1871, 202 438 acres, with intention to extend to 296 300; the future probable extension is now to 319 580 acres, with a supply of 3 945 cubic feet per second passing through the main canal. The details of distribution, through the canals, are given in the subjoined lists.

The expenditure on the works after 1866–67 seems to enter a new phase of account, as the official returns show, in mentioning total expenditure, which thus means total, exclusive of expenditure before 1866–67.

From the following tables it will be observed that it is intended, after improvement of the distribution in some parts, and a general improvement of the channels of the central delta, to extend the total irrigation to 612 000 acres; that is an increase of about 60 000. The original scheme of 1847 was intended to apply to 615 000 acres, or about half the gross cultivable area of the delta. The area under water command is now 771 624 acres, and the supply of water carried by the canals is enough for the intended area. The length of navigable communication will be nearly 500 miles. The project will then be treated as completed, any fresh extension of works being nominally independent. It will then have cost £1 108 870, and will yield a net profit of 12·7 per cent.

It will be noticed that the chief differences between this project as executed, and the original scheme as laid down by Major Cotton, are (1) the whole drainage of the delta is effected; (2) the extension of canals for navigation; (3) the superiority and completeness of the whole destribution. While these three points affect the cost, the present mode of complete account, including establishment charges and interest, also affect the figures showing cost and profit.

Remarks.—The whole remains a marvel among economic irrigation works. Even after allowing for the low cost due to

the very shallow foundations usually adopted in Madras, the project of Michael Topping should certainly not have been shelved in the last century. It now supports a population of two million human beings, whose annual imports are valued at £500 000 sterling; their exports at about double that amount. The wisdom of Sir Henry Montgomery's furtherance of a scheme, then considered hare-brained, has been amply proved.

Godavari Deltaic Works.—Expenditure on Works only from 1847 to 1867.

Year.	Head-works.	Eastern Delta.	Central Delta.	Western Delta.	On all Works.
	£	£	£	£	£
In 1847 to 1851 ..	91 121	4 941	850	1 666	98 578
,, 1852	4 787	4 491	21 586	6 517	37 381
,, 1853	2 217	7 188	5 244	8 103	22 752
,, 1854	—	16 141	10 805	14 661	41 607
,, 1855	—	4 533	16 575	24 277	45 385
,, 1856–57	—	7 559	10 321	16 135	34 015
,, 1857–58	—	4 739	3 321	8 013	16 073
,, 1858–59	—	368	506	3 981	4 855
,, 1859–60	—	5 891	441	4 782	11 114
,, 1860–61	—	328	1 144	6 294	7 766
,, 1861–62	28 254	1 236	3 320	6 570	39 380
,, 1862–63	—	2 150	4 066	8 135	14 351
,, 1863–64	—	2 475	4 067	4 647	11 189
,, 1864–65	—	1 436	1 318	3 753	6 507
,, 1865–66	—	239	261	1 779	2 279
,, 1866–67	—		141	3 187	4 251
Totals to 1866 ...	126 379	64 638	83 966	122 500	397 483

Godavari Deltaic Works.—

	Position of Head.	Total Length.	Length actually navigable in 1880.	To be made navigable.
	Miles.	Miles.	Miles.	Miles.
Eastern Delta Channels.				
Main	0·	4·15	4·15	4·15
Samalkot	4·15	34·35	32·94	32·94
Kokanada	4·15	27·35	27·35	27·35
Mandapetta	6·56	13·44	13·44	13·44
Bank	0·81	39·00	34·0	39·00
Koringa	13·04	24·46	22·30	22·30
Injeram	21·86	11·11	11·11	11 11
		153·86	145·25	150·31
Central Delta Channels.				
Main	0·	8·	8·	8·
Gunnaram	8·0	44·	28·	37·5
Bank	8·0	41·	35·	35·
Amalapur	8·5	31·5	27·	31·5
Billakarru	22·0	4·5	4·5	4·5
Bendamur	30·0	14·	2·	14·
		143·0	104·5	130·5
Western Delta Channels.				
Main	0·	6·08	6·08	6·08
Kakaraparru	6·06	10·36	10·36	10·36
Gostanadi, &c. ...	7·44	34·31	28·77	34·31
Bank	14·88	25·77	25·70	25·70
Mukkamala	15·06	2·40	2·40	—
Narsapur	16·42	29·84	29·84	29·84
Ellor	6·06	40·34	40·34	40·34
Attili	6·86	15·94	15·94	15·94
Junctions, &c.... ...	9·69	3·54	3·54	3·54
Weyeru, &c.	13·22	29·92	29·92	29·92
Undi	19·59	15·82	15·82	15·82
		214·31	208·44	211·91
Totals, &c.		511·17	458·25	492·72

Details of Irrigation.

Discharge originally proposed.	Water to be utilised.	Acreage originally proposed.	Highest effectual Irrigation.	In 1882 Acreage estimated for future.	Duty per cub. ft. per sec.
Cub. ft. per sec.	Cub. ft. per sec.	Acres.	Acres.	Acres.	Acres.
—	3·00	—	—	200	66
415·51	415·51	27 701	32 047	29 000	69
581·41	581·41	38 761	43 970	44 000	75
482·32	482·32	32 155	27 151	28 000	58
695·98	606·48	40 399	18 591	20 000	33
483·85	483·85	32 257	30 903	32 000	66
253·45	253·45	16 897	15 371	16 800	66
2912·52	2826·02	188 170	168 033	170 000	60
—	15·	—	—	1 000	66
—	681·	—	36 583	47 880	70
—	423·	—	24 294	29 650	70
—	447·	—	26 666	31 350	70
—	—	—	—	—	—
—	179·	—	10 127	12 540	70
—	1745·	95 000	97 670	122 420	70
—	12·	—	1 313	1 000	83
97·5	103·5	6 000	8 690	8 500	82
450·	487·5	36 200	36 946	39 000	80
337·5	294·	23 800	28 079	28 000	95
—	—	—	—	—	—
765·	765·	56 500	59 812	59 000	77
682·5	682·5	48 200	55 526	55 000	80
487·5	475·5	34 200	32 881	33 000	69
—	—	—	—	—	—
375·	513·	32 500	52 972	48 080	93
750·	612·	58 900	46 141	48 000	78
3945·	3945·	296 300	322 360	319 580	81
6857·52	8516·	579 470	588 066	612 000	72

Godavari Deltaic Works.—Revenue Account and Yearly Irrigation

Official Year.	Capital Outlay.		Gross Direct Receipts.	Share of enhanced Land Revenue.	Working Expenses.	Simple Interest.	Net Profit.	Acres Irrigated.
	During the Year.	Total.						
	£	£	£	£	£	£	£	
To end of 1866–67	—	677 409	666 924	130 256	468 387	287 336	41 457	—
For 1867–68	16 866	946 275	128 659	11 742	27 075	26 943	86 383	445 268
„ 1868–69	25 907	720 182	127 833	10 516	25 348	27 732	85 269	432 590
„ 1869–70	16 449	736 631	141 201	13 700	29 436	28 932	96 533	473 480
„ 1870–71	12 845	749 476	146 851	15 334	31 390	29 664	101 131	491 446
„ 1871–72	22 380	771 856	141 647	13 455	29 218	27 580	98 304	470 961
„ 1872–73	48 923	820 779	141 101	14 817	33 720	28 891	93 307	489 606
„ 1873–74	32 688	853 467	146 778	15 340	34 367	30 799	96 952	486 011
„ 1874–75	44 132	897 599	147 583	16 423	37 635	32 375	93 996	497 270
„ 1875–76	49 796	947 395	146 709	17 073	43 541	34 428	85 813	506 954
„ 1876–77	33 679	981 074	149 621	16 228	41 880	36 106	87 863	520 610
„ 1877–78	28 514	1 009 588	168 114	18 027	40 874	37 066	108 201	582 336
„ 1878–79	22 429	1 032 017	168 727	17 405	43 095	38 317	104 720	545 598
„ 1879–80	21 507	1 053 524	177 357	17 556	53 250	39 087	102 576	588 115
„ 1880–81	14 288	1 067 812	169 692	16 339	44 545	39 834	101 652	563 719
„ 1881–82	11 721	1 079 533	163 366	15 887	44 184	35 881	99 118	549 998
Liability at end of 1881–82	—	—	2 932 163	360 098	107 945	780 971	1 483 345	—

Godavari Deltaic Works.—Outlay between 1866–67 and 1881–82.

	Previous.	In 1881-82.	Total.
	£	£	£
1. *Headworks—*			
Buildings	621	—	3 621
2. *Canals and Branches—*			
Land	2 205	38	2 543
Regulators	4 280	—	4 280
Falls and weirs	1 728	—	1 728
Cross-drainage	2 960	345	3 305
Bridges	1 761	(–2)	1 759
Escapes	3 027	276	3 303
Navigation works...	62 047	(–66)	61 981
Earthwork and miscellaneous ...	59 537	155	59 692
3. *Distributaries—*			
Land	1 232	23	1 255
Works	15 750	1 191	16941
Earthwork	12 276	998	13 274
4. *Drainage and Protective Works—*			
Land	1 853	134	1 987
Works	5 098	1 667	6 765
Earthwork	41 062	2 272	43 334
Total	214 816	7 331	222 147
*Outlay on Expired Sanctions (till 1871)	429 907	—	429 907
Total on Works	648 344	7 331	655 675
Total on Establishment	162 086	1 709	163 795
" Tools and Plant	8 545	876	79 421
" Suspense Account	3 103	—	3 103
Total Outlay on Construction... ...	892 078	9 916	901 994
Indirect Charges	175 734	1 805	177 539
Simple Interest	745 090	35 881	780 971
Total Capital Outlay	1 812 902	47 602	1 860 504

* The expenditure up to 1871 is thus given in total:—

Cost of Works	£429 907
Establishment	89 369
Tools and Plant	51 732
Total ...	£571 008

The Kistna Deltaic Works.—The delta commencing at Bezwada, 60 miles from the mouth, or 45 miles direct, is divided into two parts, the eastern and the western deltas, between which the Kistna runs in an elevated channel. The maximum flood-discharge at Bezwada is 736 000 cubic feet per second, the river there being 3 900 feet wide, emerges from between two rocky hills; but lower down is from 1¼ to 2¾ miles wide. The total deltaic area is given at 1 160 square miles on each bank, or 2 320 in all; but this is probably under-estimated.

In 1766, there was some irrigation in both deltas: in the eastern through the Budemer and Pulleru drainage channels, amounting to 16 611 acres; in the western through the Tungabaddra channel and others, amounting to 2 355 acres; but this was dependent entirely on high flood, and hence precarious, the supply being taken through cuts in the river bank, above ordinary flood level. Near the close of the century, these works had fallen into disrepair, and the population was scanty.

In 1792, Major Beatson proposed to restore the cultivation by building a weir at Bezwada; but apparently the first design for this work was made by Michael Topping, who took the needful levels in 1795. The disturbed state of the country was sufficient to prevent anything more from being done then. The famine of 1833–34 devastated the country and drew attention to irrigation in 1835. Eventually, in 1847, Major Cotton and Captain Lake proposed a project of irrigation, and the construction of the Bezwada weir to a height of 12 feet above summer level, or 19 feet above the deep bed of the river. A committee afterwards recommended an increase of 4 feet in height. Finally, in January, 1850, the Court of Directors sanctioned an expenditure of £150 000 on the works, of which about a half was to be devoted to the weir; construction was begun in 1852.

Treating the works as divided into headworks, eastern deltaic, and western deltaic works, the expenditure on them from 1852 to 1866–7, is given in the attached table. The whole of this amounted to about a quarter of a million sterling in 15 years, of which £66 254, with £6 434 more for establishment charges, was spent on headworks before October, 1855, when the weir was completed. In recent times £2 000 more was spent in improving them.

The Headworks.—The length of weir is 3 198 feet from wing to wing; its crest is 6 feet wide and placed at 15½ feet above the level of the top of the foundations, which is the ordinary summer level of the river. The total width of apron below the crest wall is 257 feet. The foundations consist of a double row of wells, 7 feet deep and 4½ feet in diameter. There is a set of under-sluices at each end, in all 30 vents of 6 feet. The head-sluices at each end are of the same dimensions, but have their sills 6 feet and 5½ feet below crest level at the western and eastern off-take. The crest being too low for the required supply, a temporary dry-stone wall, 4 feet high, is annually built on it, and the stone is afterwards used in annual repair to the apron. (This is probably dry-pitching of the Madras type.) In future, shutters will be used instead, £13 000 having been granted for improvements to headworks.

The history of the construction of the two sets of deltaic canals, is, like that of those of Godavari, far from interesting or instructive. The sanctions to expenditure seem to have been fitful, and the works to have been carried out in scraps, perhaps with some intention of system. But in 1862 the Government ordered a complete scheme to be drawn up for the whole of the remaining works. Colonel Anderson estimated the necessary expenditure, for works only, at £309 211. At that time the total irrigated area was 190 000 acres, and the proposed works were intended to extend it to 470 000. But as no complete scheme was forwarded, the matter remained in abeyance till 1876 (*sic* in Official Report, p. 97), owing to want of establishment (engineers) and other causes. In December, 1876, fresh estimates for extended works were made, but not any complete scheme. In 1876–78 £8 234 was spent on extending the Kommamur Canal as a Famine Relief work. On February 9th, 1882, the completion estimates of the Kistna deltaic works were sanctioned, amounting to £647 000; hence the works are now in progress for completing the extended irrigation mentioned in the tabular list of channels. Nearly the whole of those channels will also be rendered navigable, in addition to the Budemeru drain, 37 miles long, in the eastern delta. The present navigable length of canals is not mentioned, but the tonnage conveyed on them was 101 446 in 1880, and 121 579 in 1881. The complete drainage works form an important part of the intended extension, at an

estimated cost of £255 613. The supply allowed is 1 cubic foot per second to 66 acres of irrigation; the details of supply through the channels are not given in the official returns; the season and conditions of supply probably vary little from those of the Godavari works. The water rate mentioned in the returns is an average of three rupees an acre over the whole area.

Kistna Deltaic Works.—Details of Irrigation.

Channels.	Position of Head.	Length.	Irrigated in 1876 and 1874.	Intended Irrigation.
	Miles.	Miles.	Acres.	Acres.
Eastern Deltaic Channels—				
Main	—	0·64	—	—
Ellor	0·56	40·	19 362	31 000
Ryves	0·64	21·84	30 000	35 000
Masulipatam	0·64	40·09	17 000	34 000
Bank	4·64	(37·75)	—	60 000
Pulleru	12·59	26·78	8 639	110 000
Pamurru Junction ...	31·25	0·50	—	—
Polraz	39·34	16·64	—	—
Bantumilli...	39·36	14·25	—	—
	—	169·73	137 723	270 000
Western Deltaic Channels—				
Main	—	13·	—	5 000
Bank	8·	45·75	17 868	70 000
Nizampatam	13·	27·98	21 545	50 000
Kommamur	13·	56·50	38 654	80 000
	—	143·22	76 067	205 000
Total	—	312·95	213 790	475 000

Kistna Deltaic Works.—Revenue Account and Yearly Irrigation.

Official Year.	Capital Outlay.		Gross Direct Receipts.	Share of enhanced Land Revenue.	Working Expenses.	Simple Interest.	Net Profit.	Acres Irrigated.
	During the Year.	Total.						
	£	£	£	£	£	£	£	
To end of 1866–67...	—	370 986	268 573	41 518	166 916	139 512	3 663	—
For 1867–68	29 663	400 649	50 803	7 448	12 793	17 217	28 241	200 874
„ 1868–69	27 508	428 157	48 869	5 784	14 403	18 628	21 622	194 415
„ 1869–70	19 241	447 398	53 585	8 103	17 409	19 935	24 344	199 775
„ 1870–71	15 076	462 474	55 204	9 128	16 230	20 796	27 306	204 982
„ 1871–72	14 290	476 764	57 085	8 546	17 185	19 548	28 898	211 102
„ 1872–73	12 592	489 356	55 631	10 344	19 611	20 090	26 274	228 532
„ 1873–74	15 133	504 489	65 214	12 504	27 024	20 652	30 042	233 842
„ 1874–75	15 086	519 575	68 967	13 111	29 381	21 369	31 328	255 118
„ 1875–76	18 125	537 700	70 876	13 353	30 612	21 993	31 624	264 259
„ 1876–77	7 749	545 449	73 039	11 900	27 854	22 542	34 543	266 060
„ 1877–78	5 662	551 111	82 656	14 439	26 168	22 841	48 086	280 328
„ 1878–79	3 720	554 831	79 293	15 441	25 591	23 059	46 084	276 195
„ 1879–80	24 490	579 321	91 698	15 686	32 325	23 607	51 452	303 363
„ 1880–81	20 430	599 751	91 843	13 072	42 470	24 570	37 875	291 791
„ 1881–82	12 027	611 778	91 520	12 856	33 065	22 466	48 845	287 074
Liability in 1881–82	—	—	1 304 856	213 233	539 037	458 825	520 227	—

Kistna Deltaic Works.—Outlay between 1866–67 and 1881–82.

Detail.	Previous.	In 1881–82.	Total.
	£	£	£
(1) *Headworks*—			
Works	37	—	37
(2) *Canals and Branches*—			
Land	1 242	279	1 521
Regulators	5 442	—	5 442
Falls and weirs	1 175	—	1 175
Cross-drainage	3 953	2 833	6 786
Bridges	2 142	79	2 221
Escapes	657	45	702
Navigation works ...	12 596	1 424	14 020
Buildings	293	—	293
Earthworks	66 663	4 092	70 755
(3) *Distributaries*—			
Land	72	5	77
Works	1 386	36	1 422
Earthworks	9 741	(–11)	9 730
(4) *Drainage and Protective Works*—			
Earthworks	305	—	305
Total	105 704	8 782	114 486
Outlay on expired Sanctions till the end of 1866–67. ...	308 176	—	308 176
Total on Works	413 880	8 782	422 662
Total on Establishment ...	104 944	2 485	107 429
,, Tools and Plant ...	31 553	207	31 760
,, Suspense Account ...	5 531	—	5 531
Total Outlay on Construction ...	555 908	11 474	567 382
Indirect charges ...	43 842	554	44 396
Simple interest	436 359	22 466	458 825
Total Capital Outlay	1 036 109	34 494	1 070 603

Kistna Deltaic Works.—Expenditure on Works only before 1867.

Official Year.	Headworks.	Eastern Delta.	Western Delta.	On all Works.
	£	£	£	£
1852 to 1855–56 ...	66 254	31 258	8 926	106 438
In 1856–57 ...	—	7 835	21 344	29 179
„ 1857–58 ...	—	5 782	3 909	9 691
„ 1858–59 ...	—	4 900	1 660	6 560
„ 1859–60 ...	—	7 308	1 141	8 449
„ 1860 61 ...	—	10 318	1 674	11 992
„ 1861 62 ...	—	7 963	5 195	13 158
„ 1862 63 ...	364	7 419	13 941	21 724
„ 1863 64 ...	—	8 530	12 214	20 744
„ 1864 65 ...	50	4 397	11 400	15 847
„ 1865 66 ...	790	2 560	6 673	10 023
„ 1866 67 ...	168	1 935	7 384	9 487
Total	67 626	100 205	95 461	263 292

The Pennar Deltaic Works.—These works are small, the delta being only 15 miles wide. Formerly the delta below Nellor was irrigated by floodcuts, or channels supplying a number of tanks; these were the Jafir Sahib, the Labur, Idur, and the Sarvapalli channels; the tanks, about 40 in all, are not large; there are four or five comparatively large. The supply from the Pennar being thus very precarious, Captain de Butts made a definite proposal in 1849 for making a weir and off-take at Nellor. In 1853 it was commenced under a sanctioned estimate for £8 555; it with its head-sluices were completed in 1857 at a cost of about £9 300. It was breached in 1857, and rebuilt; also again in 1858. Reconstruction began in August, 1859; the work was delayed by freshets, but was finished in March, 1862.

In 1869 some alteration was made; in 1870 it was seriously damaged by a high flood and repaired. In 1874 a flood cut a channel round its wing-wall; and the weir was then lengthened by about 500 feet. The improvements and connections with existing channels, enlargements of tanks and extensions of embankments, were made between 1857 and 1862. Further distribution works were carried out in 1868 and in 1876, but these were connected with additional storage.

The site of this weir was badly chosen, and the results proved the wasteful economy of building a weir of low cost in preference to a better and more expensive one in the first instance.

The existing weir is 2 039 feet long. The old portion consists of a body-wall 9 feet high on 3 feet of solid foundation, resting on two rows of wells 9 feet deep, of 7 feet external diameter. There is no direct overfall, but a series of aprons 33 feet, 25 feet, and two of 30 feet wide, divided by retaining walls with a total fall of 9 feet; and finally a loose stone apron 60 feet wide. The new portion of the weir has a body-wall of the same height, but with solid foundations $3\frac{1}{2}$ feet deep and 11 feet broad, resting on wells 6 feet deep; the aprons being like those of the old portion. There is a set of under-sluices at each end, the northern set having 10 vents, and the southern set having 5 vents, all of 5 feet each. The original head-sluices consisted of 9 vents of 6 feet broad, the additional ones of 6 vents, $10 \times 3\frac{1}{2}$ feet each; the sills are 8 feet below the weir crest. The whole was built on the sandy bed of a river, and at a place of contracted waterway, in order to save in length and cost. The channels are thus :—

Existing in 1862.	Bed Width.	Irrigation possible.	Discharge.	Actual Average Irrigation in 1870.	
				1st Crop.	2nd Crop.
Main Channels.	Feet.	Acres.	C. f. p. s.	Acres.	Acres.
Main canal	120	64 000	1 087	—	—
Jafir Sahib	30	21 950	—	33 000	500
Sarvapalli Cut ...	54	42 050	—	21 000	100
Distributaries.					
Labur	21	14 000	—	—	—
Idur	12	7 000	—	—	—
Sarvapalli	41	30 508	—	—	—
Kistnapatam ...	14	11 542	—	1 800	—

The outlay against expired sanctions mentioned in the table consisted of £31 819 on headworks, and £20 793 on channels, in all £52 612. The remunerative character of these works was not permanently established till 1877–78. The account of revenue credited seems to have been that of the collector.

The area nominally commanded by these works is 64 000 acres to the south of the river. The land to the north of the river is higher, and will be irrigated by works in course of construction at the Sangam weir across the Pennar, 20 miles above Nellor.

Pennar Deltaic Works.—Details of Cost of Works.

Detail.	Previous.	In 1881-82.	Total.
(1) *Headworks—*	£	£	£
Works	14 375	—	14 375
(2) *Canals and Branches—*			
Land	2 731	—	2 731
Regulators	3 491	—	3 491
Falls and weirs	610	—	610
Cross-drainage	1 245	—	1 245
Bridges	2 561	—	2 561
Escapes	200	—	200
Earthwork	17 335	—	17 335
Storage works	10 369	—	10 369
Miscellaneous, Preliminary and small ...	334	—	334
(3) *Distribution—*			
Storage works	1 470	—	1 470
Land	213	—	213
Works	1 244	—	1 244
Earthwork	1 319	—	1 319
Miscellaneous	24	—	24
(4) *Drainage and Protective Works—*			
Earthwork	1 267	—	1 267
Miscellaneous and small	34	—	34
Total	58 822	—	58 822
Outlay on expired Sanctions	52 612	—	52 612
Total on Works	111 434	—	111 434
Total on Establishment ...	27 858	—	27 858
" Tools and Plant ...	2 786	—	2 786
" Suspense Account ...	808	—	808
Total Outlay on Construction	142 886	—	142 886
Indirect Charges	23 630	—	23 630
Simple Interest	96 023	—	96 023
Total Capital Outlay	262 539	—	262 539

Pennar Deltaic Works.—Areas irrigated from 1860 *to* 1882.

Year.	1st Crop.	2nd Crop.	Year.	1st Crop.	2nd Crop.	Year.	1st Crop.	2nd Crop.
	Acres.	Acres.		Acres.	Acres.		Acres.	Acres.
1860-61	26 824	18	1867-68	48 498	179	1874-75	45 661	443
1861-62	26 524	202	1868-69	52 962	372	1875-76	51 367	365
1862-63	28 109	78	1869-70	54 150	196	1876-77	16 531	8
1863-64	31 654	125	1870-71	53 584	175	1877-78	51 707	5 935
1864-65	32 964	121	1871-72	50 747	69	1878-79	54 291	820
1865-66	33 543	237	1872-73	50 604	182	1879-80	56 106	1 158
1866-67	46 750	190	1873-74	50 820	145	1880-81	57 162	549
						1881-82	57 207	658

Pennar Deltaic Works.—Revenue Account after 1877.

	1877-78 £	1878-79 £	1879-80 £	1880-81 £	1881-82 £
Total capital outlay, exclusive of interest	165 580	165 725	166 516	166 516	166 516
Gross direct receipts ...	9 538	9 145	9 850	10 168	10 272
Working expenses ...	3 205	4 740	6 054	4 273	4 928
Net direct revenue ...	6 333	4 405	3 796	5 895	5 344
Total direct and indirect revenue ...	21 433	21 359	22 219	23 063	23 133
Deduction for revenue due to former irrigation works... ...	10 622	10 765	10 812	11 330	11 304
Net revenue due to the new Pennar Deltaic works	10 810	10 594	11 407	11 732	11 829
Ditto otherwise credited	3 587	3 763	3 872	3 879	3 871
Simple interest $4\frac{1}{2}$ p.c.	6 378	6 394	6 414	6 430	5 715
Net profit	3 542	1 774	1 254	3 344	3 500
Liability of works representing total profit from beginning...	—	—	—	—	8 925

Lower Kalarun Irrigation.—There was probably irrigation from the lower reaches of the Kalarun in ancient times through the Vadavar channel and four others supplying the Veeranam tank and land in the neighbourhood of it on the north bank. But details about it are not forthcoming from official reports. The large Veeranam tank has a bank 12 miles long, and contains 5 400 million cubic feet; it is doubtless ancient, and could never have been fully supplied by mere surface drainage.

When Captain Cotton diverted much of the Kalarun supply into the Kavari in 1835 and 1836, by constructing the English weir at the delta-head (*see* Kavari Deltaic Works), and at the same time caused much silting up at that place, he endeavoured to mitigate the loss of water to existing irrigation from the lower Kalarun, by constructing there a weir specially designed for that purpose.

The lower weir was built to a height of 6 feet in 1836, and 2 feet were added in 1837; but in this year it was breached, in 1838 it was repaired. The estimates appear to have been £13 524 and £3 093; but the cost of the weir is given as £7 374.

In 1856–57 the weir was extended, and a bridge made at a cost of £15 145. In 1862 the weir was damaged again; in 1864 much of it gave way, and it was reconstructed at a cost of £11 086; in 1868–69 additions were made to it costing £6 968.

This weir, situated about 30 miles above Devikota, the mouth of the Kalarun, and 67 below the delta-head, consists of two parts connected by an island. The dam of the northern part is 8¼ feet high, in two steps each 4 feet broad, they rest on 3 feet of solid (masonry?) built on wells 6 feet deep. The dam of the southern part is similar, but its height is less by 0·5 foot. There are two masonry aprons of a total breadth of 24 feet; their lower ends are supported by a retaining wall resting on foundations like those of the dam. The northern part has 60 pairs of sluices, and the southern part the same number; each sluice is 6 feet broad, the estimated waterway of the former being 1 020 feet, of the latter 1 000 feet, through sluices, and 96 feet for both through sluice arches. The linear distance occupied by the island is 1 285 feet.

Two new channels were made: one the North Rajah Voikal, to supply an area north of the Kalarun, before dependent on four

small native channels; the other the South Rajah Voikal, to supply a small area to the south of the Kalarun, in the north-east corner of the Kavari delta. The area dependent on the weir through the Vadavar channel and North Rajah Voikal was, in 1870–71, 74 617 acres. The total area to north and south irrigated from the weir was, from 1874 to 1880, according to the following table :—

	1874–75.	1875–76.	1876–77.	1877–78.	1878–79.	1879–80.
Area in acres ...	109 443	109 521	109 517	108 649	120 357	123 412
Increase of Revenue due to the works ...	£ 32 505	£ 26 840	£ 26 600	£ 31 703	£ 26 045	£ 33 977

The account of these works was formerly blended with that of the Kavari deltaic works, to which they seem to be a most unfortunate adjunct, as they interfere with the carrying capacity of the main-drainage channel of the whole delta. Perhaps their abandonment would be beneficial in that respect.

Considering these works, however, from a constructive point of view, their design and execution resembles a series of experiments to determine the theoretical weir just strong enough to stand against the conditions of the case, without any margin of safety. As such, they are exceedingly interesting and instructive. Details about the various floods and minute details about the works would be valuable.

The Anicuts of Madura.—The Suruli, the principal tributary of the Vaiga, joining it after a course of 36 miles from Gudalur, is entirely utilised in the irrigation of the Kambam valley; there are ten anicuts across it, with channels and tanks; the first is situated at half-a-mile from Gudalur, whence a canal on the left bank irrigates rice lands for 5½ miles, and eventually falls into the Kambam tank; the others irrigate a narrow strip of rice cultivation on each bank in the lower part of the Kambam valley. On the Vaiga itself are two masonry anicuts, the Perani and the Chitani, situated 22 and 18 miles respectively above the city of Madura, which are said to have been built by two favourite dancing girls, favourites of one of the Naik kings of Madura; the channels from them are in bad order. Below the Chitani there are no dams, the slope of the ground allowing channels to be taken off without the aid of anicuts. The

supply of the Vaiga is so deficient in its lower parts, in the Ramnad, that any irrigation from it is only on a very small scale.

The supply of the river Gundu is very small, the local rainfall being only 18 inches yearly; on it, east of the town of Kamudil, 18 miles from the sea, is an anicut large dam, made of loosely built stone; a channel from it takes its water to the Kallavi lake. On the river Vaipar are several stone anicuts, and on its tributaries are storage tanks; the amount of irrigation effected from these two latter rivers is unknown.

The Anicuts of the Tambrapurni.—There are seven anicuts on this river. The first is the Thalay anicut, just below the falls of Papanassam, it is renewed annually with stakes and brushwood; it has two channels, one 10 miles long on the north bank, and one 6 miles long on the south, each ending in a tank. The second is the Nathiani anicut, 6 miles below the former, it is a very ancient structure, consisting of large blocks of stone placed obliquely across the river, and is 468 feet long; only one channel flows from it, for 12 miles on the north bank which irrigates 1 119 acres, yielding a revenue of £1 297. The third is the great Kannadien anicut, built of cut stone, it is 9 feet high, and has a top width of 6 feet; it has also a large rough apron varying from 35 to 160 feet in width; the anicut is divided into two pieces by a rocky island. A channel from it on the south side is 22 miles long, irrigates 9 574 acres, and yields a revenue of £17 981; the Kannadien channel flows through the town of Serun-Mahadevi, 9 miles west of Tennevelli. The fourth is the Kodagan anicut, six miles below the last, it is 2 287 feet long, of cut stone roughly put together; it has one channel from it on the north side 10 miles long, irrigating 5 433 acres, and yielding £6 106 of revenue. The fifth is the Palavur anicut, 2 miles east of the town of Serun-Mahadevi, it is 2 532 feet long, its channel on the south side is 26 miles long, supplies 54 tanks, and terminates near Palamcotta, and irrigates 2 865 acres, yielding £5 468. At a mile and a half below the Palavur is the sixth or Sutamelli anicut, 2 miles east of the town of Serun-Mahadevi, divided by a rock into two portions, its channel on the north side is 14 miles long, supplying two distributaries, passing through the town of Tennevelli, which irrigates 1 806 acres, yielding £3 299 of revenue.

The seventh anicut, 18 miles below the last, is the Murdur anicut, 27 miles from the sea; it is of horseshoe shape, 4 028 feet long, and supplies a channel on either side; its escape weir is of beautifully cut stone work. Its channels run in and out of several large tanks, and irrigate 14 400 acres, yielding a revenue of £17 700. Below this anicut are four channels, irrigating 4 280 acres, and yielding £4 980 of revenue.

The total amount of irrigation effected by these native works is 39 578 acres, yielding £56 828; the repairs only cost $1\frac{1}{2}$ per cent. on the revenue.

The estimated amount of water from this river that is utilised for irrigation is given in the brief account of the river Tambrapurni, page 281.

The English anicut at Srivekuntam, 12 miles below Murdur, will be 1 380 feet long, 6 feet high, and $7\frac{1}{2}$ feet broad, founded on wells; it will irrigate 15 000 acres on the north and 15 000 on the south bank, and supply Tuticorin with water; it was commenced in 1869, on an estimate of £83 160; in 1873 £76 878 had been spent on construction; it was, therefore, then probably nearly completed.

In 1882–83 revised estimates were prepared for the development and completion of these works. The following represents the condition at that time:—

Year.	Capital Outlay.		Charges of Year.	Revenue of Year.	Irrigation.	
	During Year.	Total.			1st Crop.	2nd Crop.
	£	£	£	£	Acres.	Acres.
1881–82 ...	—	122 445	—	—	18 770	15 680
1882–83 ..	1 363	123 808	2 563	9 635	19 546	17 647

Palar Anicut.—The narrative of these works in Chinghput and North Arkat is not available. The following figures illustrate the condition in 1882–83:—

Year.	Capital Outlay.		Charges of Year.	Revenue of Year.	Irrigation.	
	During Year.	Total.			1st Crop.	2nd Crop.
	£	£	£	£	Acres.	Acres.
1881–82 ...	—	173 183	—	—	64 560	26 221
1882–83 ...	(–13 983)	159 200	4 293	11 813	66 212	20 584

Pelandorai Anicut.—Similarly also with these works :—

Year.	Capital Outlay.		Charges of Year.	Revenue of Year.	Irrigation.	
	During Year.	Total.			1st Crop.	2nd Crop.
	£	£	£	£	Acres.	Acres.
1881–82 ...	—	33 142	—	—	2 155	31
1882–83 ...	2 212	35 354	4 776	527	3 386	174

Buckingham Canal.—For this work completion estimates were forwarded in 1883. The works suffered both from drought and flood in this year. The following are the figures :—

Year.	Capital Outlay.		Charges of Year.	Receipts of Year.	Traffic. Ton Mileage.
	During Year.	Total.			
	£	£	£	£	
1881–82 ...	—	473 349	—	12 006	12 134 232
1882–83 ...	15 904	489 253	16 155	10 787	11 755 375

NOTE.—The ton of measurement of 50 cubic feet is here adopted.

Other Canals and Anicut Works of the Madras Presidency are grouped in reports with tanks and storage works as minor works of irrigation.

The Anicuts of Maisur.

General description of Works.—The ordinary stone dam or anicut in Maisur varies from 7 to 25 feet in height, it consists of a mass of dry rubble, faced with large stones, placed on a rocky site ; the front casing of stones $3\frac{1}{2}' \times 1\frac{1}{2}' \times 1'$; the rear aprons of large stone blocks $9' \times 3\frac{1}{2}' \times 2'$, each stone projecting for one-third of its length beyond that above it, or about $2\frac{1}{2}$ feet ; the interstices are filled with small rubble ; these works are unstable and leaky, allowing all the summer discharge to escape, and only supplying the channels in season of flood, when again they are easily damaged and breached ; the dams are curved and point up stream, having a length about double the width of the river, the crown is lower near the head-sluices to relieve the pressure against them in flood. The head-sluices consist of rough stone uprights, 4 or 5 feet apart with stone caps over them ; the openings being stopped with brushwood or earth filling ; they are very inefficient during floods, which frequently enter uncontrolled and make breaches.

The channels are rough trenches generally following the

undulation of the country, and very badly levelled and set out; the irrigation water is taken direct from them through cuts made in their banks, the escapes for surplus water are made in the same way; the channels suffer much from silt brought down by cross-drainage, also from breaching by the same cause; although there are rough-stone silt dams as well as solidly constructed outlets at low levels for holding up and scouring out the silt from the channels.

Results.—The financial results, as shown in the tabular statistics, appear meagre in the extreme; the causes being that not half the irrigated land is assessed, and that the irrigation water is surreptitiously taken. It appears that if all the irrigation were paid for, the tanks of the Maisur division would yield £56 900, and those of the Hassan division £84 450 more than the revenue collected; or that, roughly for the whole province £200 000 a year remains unrealised.

According to paragraph 14 of Major Pearse's letter of March 14th, 1866, two British officials, Major Montgomery and Colonel Clerk, after several attempts to induce the landholders to pay for the water, were obliged to give it up.

Works recently reconstructed.—The Maddur anicut, on the Shimsha, is founded on rock, and is 900 feet long; it raises the water-level 14 feet, and feeds eight tanks; capital outlay £9 200, net returns, £4 145.

The Sriramadevara anicut, on the Hemavatti, completed in 1870, has a length of 1 000 feet, an average height of 22 feet, and a delivery of 400 cubic feet per second; outlay £35 000, estimated net returns £9 600, at a duty of 40 acres to the cubic foot per second supply, and a water rate of 12s. per acre; this gives a percentage of 27 per cent. on the capital.

The Marchalli anicut, on the Lachmantirth, has a length of 268 feet, and raises the water 12 feet; outlay £2 388, estimated returns about 27 per cent.

Later information is not available in 1882, as the province has passed out of British administration.

The Anicuts of Maisur.—Statistics for 1864–65.

Division.	Rivers utilised.	Aggregate length of Channels. Miles.	Revenue realised in 1864-65.
I.—Maisur	...Kávari, Lachmantirth, Shimsha, Nugu	461	24 025
II.—Hassan	...Kávari, Himavatti, Yegachi, its branches, Shimsha	232	5 910
III.—Kaddur	...Vadvutti, Biranji, Kirisandisamudram	148	3 456
IV.—Naggar	...The tributaries of the Tungabaddra	362	3 791
	Total ...	1 203	37 182

I.—Abstract for the Maisur Division.

Name of Anicut.	Length of Channel.	Measured Discharge.	Irrigable area at a duty of 40 acres.	Assessment due at the rate of 15s. per acre.	Revenue realised in 1864–65.
From the Kávari.	Miles.	C.ft.p.sec.	Acres.	£	£
Saligram	13	40	1 600	1 200	717
Mirlao	40	151	6 060	4 545	1 924
Chanchamcattai... ...	24	123	4 920	3 690	1 212
Tippur	22	83	3 320	2 490	616
Chikdeoraj	75	448	17 920	13 440	6 070
Davroi	8	73	2 920	2 190	468
Vijjianaddi	35	240	9 600	7 200	3 262
Bangardodi...	9	90	3 600	2 700	758
Ramasami	31	118	4 720	3 540	2 369
Do.	30	118	4 720	3 540	1 287
Talkad	18	153	6 120	4 590	1 288
From the Lachmantirth.					
Hanagod	17	335	13 400	10 050	1 211
Kattai Malwadi	14	140	5 600	4 200	239
Harganhalli	12	150	6 000	4 500	237
Do.	17	224	8 960	6 720	289
Sagar	20	—	—	—	498
Cholenhalli	6	—	—	—	148
From the Shimsha.					
Maddur	12	56	2 240	1 680	728
From the Nugu.					
Lachmanpura	4	135	5 400	4 050	704
Total	461	2 677	107 100	80 325	24 025
Average per cubic ft. per second of discharge ...	...	... 1	40	£30	£9

The Anicuts of Maisur.—Statistics for 1864-65 (*continued.*)

II.—Abstract for the Hassan Division.

Names of Rivers.	Number of Anicuts.	Number of Channels.	Length of Channels.	Revenue realised in 1864-65.
			Miles.	£
Yegachi	—	4	15¼	472
Kávari	—	2	53	2 010
Himavatti	—	8	112½	2 821
Branch of Yegachi	—	4	46	588
Shimsha	—	1	5	19
Total ...	—	19	232	5 910

III.—Abstract for the Kaddur Division, including Chikmaglur.

Names of Rivers.	Number of Anicuts.	Number of Channels.	Length of Channels.	Revenue realised in 1864-65.
			Miles.	£
Vedavatti	56	75	120½	3 086
Billah	1	1	1½	23
Biranji	6	6	13½	340
Kirisandisamudram	1	—	2	7
Total ...	64	82	138	3 456

IV.—Abstract for the Naggar Division, Shemogah and Kaddur.

District.	River System.	Number of Anicuts.	Length of Channel.	Revenue realised in 1864-65.
			Miles.	£
Sagar ...	Sheravatti	46	8½	878
	Warda	22	14	
Naggar ...	Sheravatti	19	6½	75
Kaulidrug ...	Tunga	7	6	69
Lakawali	Baddra	15	107¼	518
	Tunga	2	7	
Surab ...	Warda	22	17	406
Shikarpur ...	Choardi	8	25½	183
	Warda	3	4	
Shemogah ...	Tunga	22	63	900
Henuahalli ...	Tungabaddra ...	3	—	22
Terrikerrai ...	Baddra	4	2½	5
Anantapur ...	Warda	4	5¼	135
	Choardi	4	8	
	Sheravatti	5	11	
Wastara ...	Biranji	64	77½	600
	Total ...	250	362	3 791

General Statistics of Storage Works for the Year 1882–83 (*incomplete*).

Storage Works.	Number of Tanks.	Capital Outlay.	Gross Receipts.	Net Revenue.	Irrigation in 1882–83.	Working Expenses.	Land Revenue or Enhancement.
North-Western India.		£	£	£	Acres.	£	£
Rajputana Tanks	295	151 314	10 338	5 459	27 462	—	—
Guzrat Tanks, &c. ...	included	with Bombay					
North-E[illegible]stern India.							
Dehli and Gurganw Works...	40*	18 341	3 214	—	16 533*	1 413	2 453
Agra Irrigation Works ...	—†	22 312†	—	—	unknown†	900	—
Bandalkhand Irrigation ...	13	8 292	842	—	3 287	499	306
Southern India.							
Oriss[illegible] Central Provinces	unknown	—	—	—	unknown	—	—
Bara[illegible]d Tanks ...	18	unknown	unknown	—	unknown	—	—
Bomba[illegible] Tanks ...	17	—	3 379	—	7 282	—	—
" [illegible]anks ...	9 003	—	44 584	—	138 269	—	—
Haidara[illegible]ks	unknown	unknown	unknown	—	unknown	—	—
Madras Presidency. Chem[illegible]Tank ...	1	73 659	3 038	3 330	12 763	(−292)	54
Madras Presidency. Madra[illegible] ...	3	171 000	4 711	3 499	7 435	1 213	1 593
Madras Presidency. Imperi[illegible] ...	unknown	none	517 887	—	1 360 405	152 510	318 304
Madras Presidency. Minor [illegible]ks ...	unknown	none	330 686	—	1 165 389		
Maisur Tanks	26 452‡	299 670	—	—	2 169 040‡	—	—
Madura and Travankur ...	unknown	—	—	—	unknown	—	—

* In 1873–74. † In 1865. ‡ In 1862, including many useless.

STORAGE WORKS, TANKS, LAKES AND WATERWORKS.

NORTH-WESTERN INDIA:—

Rajputana Irrigation Works ... ... Ajmir and Merwara.
Dehli and Gurgaon Irrigation Works ... Gurgaon and Dehli.

NORTH-EASTERN INDIA:—

Agra Irrigation Works ... ... Agra.
Bandalkhand Irrigation Works ... Jhansi and Hamirpur.

SOUTHERN INDIA:—

Tanks of the Central Provinces and Berar.
Tanks of the Bombay Presidency.
Tanks of Haidarabad (Dakhan).
Tanks of the Madras Presidency.
Tanks of Maisur.
Waterworks of the cities of Bombay, Madras, Nagpore, Akola.

RECLAMATION AND PROTECTIVE WORKS IN INDIA AND BURMAH.

The Irrawaddi Deltaic Reclamation.
Lahor Protective Works.
Phillawur Protective Works.
The Gandak Protective Works.
The Indus Protective Works.
The Satlaj Protective Works.
Madras Protective Works.

Brief Accounts of Indian Reservoirs.

North-Western India.

The Rajputana Irrigation Works in Merwara and Ajmir consist of a number of reservoirs, or tanks, having banks generally of earth, though in many cases pitched or faced with rubble, and having masonry weirs and escapes; they were made or reconstructed under the orders of Colonel Dixon, the political agent, and had the beneficial effect of settling the rather troublesome population of those districts, and increasing it from 39 658 in 1835 to 130 282 in 1845. The cost of original works was according to old accounts only £24 111, from 1835 to 1846, and resulted in an increase of annual revenue of £11 300 in addition to £9 680 obtained annually till then. The following are data of these works according to old accounts :—

Tank	Surface.	Contents.	Irrigation.
	Acres.	Cub. yards.	Acres.
Lusani ...	278	5 614 400	273
Loharwara	161	3 900 000	—
Kabra ...	182	4 302 222	204
Kalikankar	182	3 699 996	437
Durathu ...	167	4 701 666	—
Sarnagar ...	109	2 934 688	—
Tarwaja ...	218	387 200	364
Rupana ...	25	524 080	36
Gohana ...	94	2 684 586	250

The extreme depths varying from 15 to 28 feet.

In 1867 these works were examined by Captain F. J. Home, R.E., an officer of great experience in irrigation, and the accounts of their financial results, which were then considered exaggerated entirely readjusted: it is from his report therefore that the abstract of financial results given in the tabular statistics has been compiled. In consequence of the number of tanks, nine varying so considerably from that for which the more recent returns are given, namely, six, it is impossible to institute a perfect comparison between the two sets of returns; but it is perfectly evident that the gross return of 47 per cent., shown by the older returns, may be generally correct. It appears also, according to other accounts, that the total number of tanks in Merwara must be considerable, as they cover a total area of 8 675 acres, and irrigate 14 826 acres of land.

Between 1872 and 1882 more tanks have been made (*see* later returns); but the name of the engineer is not given. He made the following useful observations on evaporation :—

Rajputana Tanks.—Loss by Evaporation, observed by the Executive Engineer.

Year and Month.	Exposed to Wind.		Sheltered from Wind.		Hygrometer, Daily Average.		
1882.	Number of days.	Loss in feet.	Number of days.	Loss in feet.	Wet.	Dry.	Diff.
April	30	1·1	30	0·7	89	69	20
May	31	1·4	30	1·2	94	76	18
June	30	1·3	30	0·9	93	79	14
July	18	0·3	14	0·2	83	78	5
August	25½	0·5	24	0·3	82	76	6
September ...	27	0·7	26	0·3	84	75	9
October	31	0·9	—	0	84	67	17
November ...	30	0·6	—	0	74	59	15
December ...	31	0·4	—	0	70	58	12
1883.							
January	30	0·3	26	0·3	65	55	10
February	28	0·3	28	0·4	67	54	13
March	31	0·6	31	0·5	81	63	18
Annual Evaporation		8·4		4·8			
Annual Rainfall ...		2·0		2·0			
Annual Difference		6·4		2·8			

NOTE.—The depth of the evaporating water is not given.

Mansun from 29th June to 13th September with intervals.

Khárif irrigation from 1st September to November.

Rabbi irrigation from 15th October to 10th March.

The chief crops are Maize, Barley, Wheat, Cotton and Grain, in this order.

In the other states of Rajputana still under native rulers, there have doubtless been a large number of tanks; and it is probable that Rajputana was as much developed in this respect as its physical conditions and limited rainfall allowed. In Udaipur there are still one or two magnificent lakes, and in Marwar, Jaipur, and Bhartpur, there are traces and ruins of large reservoirs, in some

cases nearly obliterated by drift sand; the primary cause of the decay of these states was doubtless their proximity to the seat of government of the Mughal emperors, who plundered and devastated them; and it would at first sight appear surprising that under British suzerainty they have not recovered and reconstructed their large and numerous reservoirs of irrigation. The causes are probably these: these states do not yet possess the confidence of the British capitalist; and hence, in order to carry out extensive works, they would have to borrow from native bankers at an interest of 10 or 12 per cent., while the works under good management would probably eventually only pay 18, and in a partially developed state only 9 per cent.; in the second place, in order to design and execute the works really well, they would require the services of skilled civil engineers. On this latter point, difficulties are thrown in the way by British officialism. In former times, Englishmen and Europeans were prevented from entering into the service of native princes from fear of their using their skill in assisting in military operations and rebellion against the British Government: at present, although this fear can hardly be said to exist, the tradition still remains in the minds of the British political agents, many of whom prevent the native princes from engaging the services of independent Englishmen, and by persevering in this childishly weak policy, put an effective bar to the development of agriculture, and consequently to the material progress of native states.

Reservoirs in Merwara and Ajmir.—Irrigation and Financial Results.

By LIEUT. F. J. HOME, R.E., in 1866.

Name of Tank.	Surface of Tank when full.	Mean Depth of whole Tank.	Contents of Tank when full.	Area irrigated from Tank.	Amount of Storage irrigated per Acre.	Gross Revenue due to Tank.	Gross Revenue per Acre irrigated.	Gross Value of one million cubic feet of water in Tank.	Capital expended.	1866–67. Balance of		1866–67 Net percentage on Capital.	
										Income.	Charge.	Gain.	Loss.
	Sq. ft.	Feet.	Cubic ft.	Acres.	Cubic feet.	£	£	£	£	£	£	£	£
1. Lusani ...	9 525 600	8·0818	76 984 185	192·	400 771*	141	0·734*	1·831	1 113	762	—	6·85	—
2. Dewatan ...	6 350 400	6·3045	40 036 224	303·	132 133	158	0·521	3·950	1 330	853	—	6·41	—
3. Kabra ...	7 938 000	—	57 693 384	58·	995 400*	112	1·933*	1·943	767	660	—	8·60	—
4. Kalikankar	7 938 000	7·268	55 932 220	339·	175 409	144	1·424	2·572	2 479	124	—	0·50	—
5. Durathu ...	17 424 000	7·3368	127 836 403	448·	285 260	147	0·327	1·376	3 171	—	291	—	0·92
6. Niran ...	13 939 200	7·6216	106 239 286	914·	116 243	560	0 612	5·271	3 208	3 865	—	42·05	—
Total ...	—	—	—	2 254·	709 945	1 362	1·884	16·943	12 068	6 264	291	—	—
	—	—	—	—	—	—	—	—	—	5 973	—	—	—
Averages ...	—	—	—	—	177 261	—	·471	2·824	—	—	—	4·96	—

N.B.—Figures marked thus (*) in columns 5 and 7 to be omitted in striking averages; the area irrigable from the Lusani and Kabra tanks being very small in comparison with their cubic contents.

Rajputana Tanks.—Irrigation and Revenue in 1882–83.

	Names.	Number of Tanks.	Com-manded.	Irrigated.	Khárif.	Rabbi.	Lift.	Double Cropped	Capital Outlay.	Gross Receipts.	Net Revenue.
			Acres.	Acres.	Acres.	Acres.	Per cent.	Per cent.	£	£	£
Old Tanks.	Ajmir	79	13 359	12 456	5 190	7 266	5	19	42 067	4 848	3 419
	Beawar	207	12 831	10 125	3 871	6 254	7	23	17 325	3 103	1 016
	Todgarh ...		3 977	2 637	342	2 295	20	29	11 250	1 399	505
	Total	286	30 167	25 218	9 403	15 815	7	23	70 641	9 350	4 939
Large New Tanks.	Bir	—	602	602	—	602	2	0	21 169	215	149
	Rajosi	—	363	363	49	314	0	0	4 004	168	125
	Ladpura	—	210	146	79	67	23	0	6 213	69	(−40)
	Makrera	—	88	65	—	65	0	0	9 268	38	5
	Balad	—	559	553	199	354	3	2	10 308	271	143
	Jalia	—	518	515	66	449	0	0	29 710	229	138
	Total ...	9	2 340	2 244	393	1 851	3	—	80 673	988	520
	Grand Total ...	295	32 507	27 462	9 796	17 666	7	—	151 314	10 338	5 459

The large new tanks were made between 1876 and 1881. Some small new tanks are included with the old tanks.

North-Eastern India.

The Dehli and Gurgaon Irrigation Works.—These works, consisting of lakes and reservoirs, have for their object the irrigation of the country south of Dehli, and in the Gurgaon and Rohtuk districts, a great deal of which is broken by small ranges of low hills. Attention was directed to these districts by the fearful famine of 1860, and the Government of the Panjab then ordered that works should be commenced to relieve the fearful destitution and starvation then existing; the country was therefore examined, and surveys and projects made by the assistant engineer in sole charge, for the construction of storage reservoirs in the Gurgaon and neighbouring districts. The larger reservoirs and artificial lakes in the Dehli districts, originally constructed by the Mughal emperors, Akbar, Firoz Shah, Aurang Shah, and Firoz Toghlak, have been reconstructed and renewed since British occupation.

The natural basins in the Dehli district are:—

1. The Najafgarh Jhil, filled by the Sahib and its affluents.
2. The combined Kotila, Chandni, Malab, and Rajira Jhils.

These collect the drainage of the surrounding country, and saturate the land submerged; the water is then drawn off by escape channels, and the beds of the jhils are cultivated. The superintendence of these works was originally under Mr. Batty.

The artificial reservoirs, twenty-four in number, are formed by damming streams and brooks, or outfalls of natural lines of drainage; they have weirs and escape channels; irrigation is thus given to the lands above the embankment, which are cultivated after submersion, and to lands below by means of the supply given through the channels. The names of these reservoirs, forming a separate charge, were:—

In the Dehli District.

1. Tilpat.	5. Khirki.	9. Bijwasan.
2. Palam.	6. Naryanah.	10. Aurangpur.
3. Yahia Nagar.	7. Toghlakabad, No. 1.	11. Ambarheri.
4. Chattarpur.	8. Toghlakabad, No. 2.	12. Badli.

In the Gurgaon District.*

1. Tharsa.	6. Raisinah.	10. Bahari.
2. Gwalpahari.	7. Bar Gujar.	11. Jhand Sarai.
3. Ghatta.	8. Dahina.	12. Garhi Harsaru.
4. Pattri Katal.	9. Nand Rampur Bas.	13. Banarsi.
5. Kala.		

* Note.—In more correct spelling, this is Gurganw.

Besides the above-mentioned, the others affording irrigation, but not paying water rate, were :—

Dehli District.

Talkatora.	Shikargah.
Naryanah.	Basantnagar.
Malcha.	Hauzkhas.
Mahpalpur.	Humayunpur.
Harjokri	Saltanpur.

Also at some of the places and villages mentioned there are two reservoirs; and some of these supply irrigation to lands in two districts.

Both the jhils and the storage reservoirs are entirely dependent for their supply on the annual rainfall, and many of them being shallow, the loss from evaporation is very great: unfortunately also, several of the reservoirs constructed in and shortly after 1861 were very defective, both in level and in alignment, their construction having been entrusted to native clerks of the collectors' law courts, in preference to the engineer that projected them, who was the author of this book. Some of these dams were of equal height from the ground, that is, of varying crest level; others were serpentine in plan, following village boundaries in alignment; these specialities, as well as others more curious, being due to Mr. Ford, Deputy Commissioner of Gurgaon.

Even under these extreme disadvantages, the works paid in 1872–3 as much as 10½ per cent., although the water rate was increased only two years before. Of the total acreage irrigated in 1872–73, 10 919 acres were under crops, three-quarters of which were wheat, and 168 acres in grass; 7 666 acres being supplied by the reservoirs, and 3 421 acres by the natural jhils. The estimated value of the crops of the year was £40 207, irrespective of the plantations, which at present consist of 14 300 trees. Later returns for 1868 to 1878 are given.

In 1870 the Tilpat reservoir was removed to make way for the Agra Canal works. Possibly most of the rest became subsidiary to them after 1878; but there is no account of it available.

The works are, according to figures, not very remunerative; this was partly due to the interference of civil officials, collectors and magistrates, both with the arrangements for original construction and with those of payment for irrigation.

One of them was so aligned as not to retain any water at all perhaps others did. The water rates appear to have been fixed not on fair principles, but at will, at rates of 3 annas and 6 annas an acre, or fivepence to tenpence. At other places, where natives were the real, not the nominal landholders, the rates have been fixed by the collectors at one-fourth the produce generally, or at a half on waste land irrigated and leased.

The only remedy for such difficulties would be to forbid British officials from holding land anywhere in India, either in their own names or the names of natives; and to subject them to instant dismissal for breach of this rule, or for neglecting to aid in introducing irrigation proposed by competent persons.

The actual income from these works principally consisted in an enhancement of land revenue of £2 453, which was permanent for several years about 1870; and in results from sales of timber and grass, the actual water rate being small.

Dehli and Gurgaon Storage Works.—Later Returns.

Year.	Capital Account.	Repairs and Working Expenses.	Gross Total Income.	Irrigation.	Annual Rainfall.
	£	£		Acres.	Feet.
1868–69	—	—	—	3 063	1·34
1869–70	18 383	1 214	—	9 746	1·64
1870–71	18 383	1 779	2 873	8 391	1·38
1871–72	18 383	1 152	2 971	7 794	1·37
1872–73	18 383	1 096	3 019	11 087	—
1873–74	18 341	1 413	3 214	16 533	—
1874–75	18 341	2 376	2 928	9 428	—
1875–76	18 341	1 258	433	8 414	—
1876–77	18 341	1 230	455	9 303	—
1877–78	18 341	490	649	2 098	—

NOTE.—The discrepancies are due to new mode of account.

Dehli and Gurgaon Irrigation Reservoirs.—Irrigation and Revenue.—Earlier Returns.

Year.	Capital Outlay.	Direct Income.	Increased Land Revenue.	Gross Returns.	Working Expenses.	Net Returns.	Acreage Irrigated.			Rainfall.
	Total Results up to the end of each Year.						During the Year.			
							Kharif	Rabbi.	Total.	
	£	£	£	£	£	£				Feet
1859–60	14 843	694	23 507	24 201	6 916	17 285	—	—	—	Unknown.
1860–61	15 251	721	25 074	25 795	7 137	18 657	—	—	—	"
1861–62	15 251	1 006	26 641	27 646	7 348	20 298	—	—	—	"
1862–63	15 251	1 102	28 208	29 310	7 905	21 405	—	—	—	"
1863–64	16 791	1 453	29 775	31 227	8 965	22 262	—	—	—	"
1864–65	16 914	1 776	31 342	33 118	10 337	22 781	738	2 057	2 795	"
1865–66	17 010	2 122	32 909	35 031	12 069	22 963	1 943	5 504	7 447	"
1866–67	17 010	2 269	35 362	37 631	12 823	24 808	1 620	7 552	9 172	1·4 to 3·4
1867–68	17 530	2 419	37 815	40 234	13 349	26 884	5 347	8 253	13 600	1·7 to 3·1
1868–69	18 255	3 048	40 267	43 315	14 299	29 017	1 021	2 042	3 063	0·9 to 1·7
1869–70	18 338	3 238	42 720	45 958	15 529	30 429	1 580	8 166	9 746	1·1 to 1·9
1870–71	18 338	3 712	45 173	48 885	17 308	31 577	1 306	7 085	8 391	1·1 to 1·6
1871–72	18 338	4 246	47 626	51 872	18 460	33 412	1 857	5 937	7 794	0·7 to 2·3
1872–73	18 338	4 684	50 079	54 763	19 557	35 206	2 108	8 979	11 087	1·7 to 2·5

The Agra Irrigation Works.—These works consisted mainly of the Fattahpur Sikri basin, and its channels the Khairagarh and Barkol, which were supplied with water by the Utangan torrent. The latter rises in Jaipur, flows through Bhartpur, and enters the Agra district about 7 miles east of Fattahpur Sikri. The revenue derived was not only from the water that passed into the channels from the overflow of the Utangan, but from the cultivation of a portion of the area of the basin itself. The irrigation from these works being very irregular, and objections having been raised against them on sanitary grounds, the works instead of being improved, were abandoned in 1865. At that time the capital outlay had amounted to £22 312, and the total direct income was £11 077, independently of increased land revenue, which probably amounted to as much more; the yearly direct income varied between £400 and £1 400, the working expenses from £600 to £1 200. It would appear therefore that, as also in the more recent case of the Agra Canal, irrigation from which is not to be allowed within 5 miles of Agra, there were some local magistrates and tax collectors having traditions opposed to irrigation. Latterly the irrigation from the Agra Canal has supplied the wants of the neighbouring districts.

The Bandalkhand Irrigation Works consisted in 1872 of five lakes and reservoirs in the Hamirpur, and seven in the Jhansi districts; they have unfortunately remained under the control of the tax collectors, and little is known of the correct amount of land irrigated by them; a certain amount is irrigated free of water rate, although an increased land rate is levied on it. The names of the tanks and lakes are:—

In Jhansi.	Miles of Distributaries.	Acres Irrigated.
Kucha Bhawar ...	3½	7
Barwa Sagar ...	8½	260
Kuchni	16	164
Pachwara ...	11	10
Total ...	39	441
In Hamirpur.		
Bijanagar, three ...	7	176
Dasrapur, four ...	2	254

In Hamirpur.	Miles of Distributaries.	Acres Irrigated.
Thannah ...	5	246
Tikaman ...	1	48
Paswara tank ...	—	9
Kirat Sagar ...	¾	11
Maddan Sagar ...	¾	101
Kallian Sagar ...	¾	32
Bijanagar tank	—	1
Phulbagh	2	157
Bela Tal tank ...	—	135
Total ...	19¼	1 170

The former works irrigate the land of thirteen villages, the latter that of sixty-one; about three-quarters of the crops grown are cereals, including rice and one-fifth sugar-cane. Some approximate financial results of these works will be found in the tabular statistics. It is in contemplation to increase the irrigation from these works to 22 000 acres.

In 1882, the following were the lengths of channel from the respective lakes:—

Jhansi.	Miles.	*Hamirpur.*	Miles.	*Hamirpur.*	Miles.
Barwa Sagar ...	8	Kirat Sagar ...	1·	Dasrapur ...	2·90
Pachwara ...	11	Maddan Sagar ...	2·50	Thannah ...	5·20
Magarwara ...	10	Kallian Sagar ...	0·80	Tikaman ...	1·20
Kachnio ...	8½	Bijanagar ...	5·20	Niagaon ...	0·50
				Bela Tal ...	6·00

The amount of water expended in irrigation in 1882 varied from 207 714 to 362 555 cubic feet per acre of irrigation, as a mean between Rabbi and Kharif supply to a crop in the Jhansi districts; the extremes being 207 086 to a Rabbi crop, and 422 579 to a Kharif crop. In the Hamirpur district, the extremes reached were 106 236 and 5 507 704 cubic feet, both to Rabbi crops, per acre. The total irrigation effected in 1882–83 was then:—

	Kharif. Acres.	Rabbi. Acres.	Total. Acres.
Jhansi series	237	1 204	1 441
Hamirpur series	76	1 111	1 846
Total ...	313	2 315	3 287

Bandalkhand Irrigation Reservoirs.—Irrigation and Revenue.—Earlier Returns.

Year.	Capital Outlay.	Direct Income.	Increased Land Revenue.	Gross Returns.	Working Expenses.	Net Returns.	Interest Charges.	Acreage irrigated. Knarif.	Acreage irrigated. Rabbi.	Free Irrigation.	Exclusive of free Irrigation. Total.
	Total Results up to the end of each Year.							During the Year.			
	£	£	£	£	£	£	£				
To end of 1864	—	—	—	—	15						
1864–65	—	—	1 002	1 002	136	866					
1865–66	290	186	1 297	1 484	573	910	—	65	564	Amount unknown.	649
1866–67	2 291	288	1 600	1 889	986	903	15	178	715		893
1867–68	3 033	401	1 933	2 334	1 409	926	129	195	598		793
1868–69	5 693	549	2 199	2 748	1 756	992	281	347	993		1 340
1869–70	6 550	746	2 449	3 196	2 685	511	565	231	731		962
1870–71	7 105	934	2 704	3 638	3 261	377	893	417	529		946
1871–72	7 105	1 099	2 959	4 058	3 732	326	1 212	306	877		1 183
1872–73	7 203	1 318	3 214	4 532	4 278	254	1 532	310	1 300		1 610

N.B.—These works having been under the charge of the collectors, the correct financial condition—even the true extent of irrigation—cannot be arrived at. The above affords a very rough indication of the real state.

Bandalkhand Irrigation Works.—Revenue Account in Pounds Sterling, based on Assessments.

Year.	Capital during Year.	Total Outlay.	Working Expenses.	Direct Revenue.	Indirect Revenue.	Net Returns.	Interest on Outlay.	Net Profit.
	£	£	£	£	£	£	£	£
1870–71 ...	555	—	—	—	255	—	320	—
1871–72 ...	—	6 955	520	(–307)	255	(–52)	313	(–365)
1872–73 ...	980	7 203	547	259	255	(–34)	317	(–353)
1873–74 ...	238	7 441	779	434	255	(–91)	322	(–415)
1874–75 ...	817	8 257	626	430	130	(–656)	326	(–401)
1875–76 ...	—	8 257	633	313	130	(–190)	337	(–527)
1876–77 ...	—	8 257	490	298	130	(–62)	337	(–399)
1877–78 ...	5	8 262	375	531	130	286	337	(–185)
1878–79 ...	—	8 262	557	316	130	(–111)	367	(–398)
1879–80 ...	—	8 292	440	336	130	258	337	(311)
1880–81 ...	—	8 292	520	293	418	191	337	(–146)
1881–82 ...	—	8 292	523	401	306	245	300	(–55)
1882–83 ...	—	8 292	499	436	306	243	332	(–89)

Southern India.

The Tanks of the Central Provinces and of Barár are, like those of Bombay, comparatively few and generally of small size; the Kanhan reservoir project, which involves a storage reservoir covering 41 square miles, a main canal 142 miles long, and minor channels of 400 miles in the aggregate, is still not commenced. In Barar, a fertile cotton producing province that would gain enormously from the advantages of irrigation, the tanks are few, small, and in a neglected condition: it was at one time imagined that any large storage projects for irrigation in this province would be perfectly impracticable owing to the configuration of the country; yet in 1870, three large storage reservoirs were proposed at Donad, Balapur, and Akola, as well as several smaller ones, by a civil engineer appointed by the Government of India. Most of these detailed projects were then set aside by the provincial head of the Public Works Department, a military man incapable of judging about matters of irrigation. In this province the opposition of the magistrates to irrigation was so great that they turned out a civil engineer from a rest-house, while helpless from choleraic attack, in the hope of ending him. Under more enlightened auspices, Barar would have become a well irrigated and permanently prosperous province.

Between 1872 and 1878, the irrigation department of Barar having been abolished, the larger projects were set aside; but some of the smaller projects, as well as a few village tank restorations, were carried out by an assistant under the buildings department of Public Works. These were:—

Buldana	Chikalda	Karinja
Sindkher	Yotmal	Tallagaon
Arali	Wun	Shiagaon
Fattahkalda	Kayar	Kutasa
Ambona	Chatwan	Kher
Gossir	Rissod	Rel

Some small dams were also made at Akola and Balapur, in 1873; but not in accordance with the larger projects before mentioned. The Nalganga and Wagdo large projects were not even attempted on the petty scale of village tanks; which the obstructive tax collectors usually permit.

Since 1878, the construction and restoration of village tanks have entirely ceased; and no irrigation works have since been attempted in Barar until 1883, or later.

The Tanks of the Bombay Presidency are comparatively few, and there is little information about them available in 1872. In the district of Nimar in the Narbada Valley, is the lake of Lachma, a tank three miles in circumference; this with 105 other tanks have been restored since the British occupation. The Chuli tank on the Chuli ravine, and the Mandleshwar tank on the Chapra, both in the Narbada territory, were restored in 1846 by Captain Trench.

In Gujrat a reservoir project, in connection with the Tapti, intended to irrigate 194 000 acres, was being carried out in 1872.

In Khandesh, a storage reservoir in the Girna Valley, and the Mukti reservoir, near Dhulia, were then being constructed: the latter has a catchment basin of 50 square miles, which, with a rainfall of 16½ inches, will collect 477 million cubic feet, of which the tank will hold about 346 millions. The Hartola tank, in the same district, was nearly completed in 1872.

In Dharwar, the Madak tank had recently been constructed; and some storage works in the valley of the Yerla, a tributary of the Krishna, were being made in 1872.

The Ekruk tank on the Adila, a tributary of the Bhima, in the neighbourhood of Sholapur was completed in 1869, and supplied water for irrigation in 1871.

The Mutha tank has been included among canals; also the Mukhti and the Pingli tanks. (*See* Canals of the Bombay Presidency.)

The irrigation from tanks in 1882 is shown in the two following tables. Details of the Ekruk scheme, the largest of them, are given separately.

The Larger Tanks of the Bombay Presidency.—Irrigation in 1882.

District.	Tank.	Commanded.	Irrigable.	Irrigated.	Gross Receipts in 1882-83.
		Acres.	Acres.	Acres.	£
Khandesh ...	Hartála ...	584	527	101	8
	Mhasva ...	4 647	2 145	187	112
Ahmadnagar	Bhatodi ...	15 126	12 124	1 023	176
Puna	Matoba ...	10 700	7 133	1 932	494
	Kásurdi ...	597	478	160	23
	Shirsuphal ...	4 500	2 500	200	12
	Bhádalwáde...	1 900	1 520	131	34

The Larger Tanks of the Bombay Presidency—(continued).

District.	Tank.	Commanded.	Irrigable.	Irrigated.	Gross Receipts in 1882-83.
		Acres.	Acres.	Acres.	£
Sholapur ...	Koregaon ..	—	—	—	17
	Ashti	15 632	13 459	248	95
	Ekrúk	17 149	15 318	1 306	820
Sátára	Nehr	8 510	7 159	749	435
	Maini	4 876	4 625	742	429
Dharwar ...	Dámbal ...	3 955	3 885	21	58
	Mávinkop ...	—	—	—	85
	Gadikere ...	—	—	—	371
	Madag	2 255	1 730	482	210
	Kalala	—	—	—	—
	Total ...			7 282	3 379

Tanks Collectively under Supervision of Collectors.

Collectorate.	No. of Tanks.	Irrigation.	In 1882-83.	Gross Receipts in 1882-83.
		Acres.	Acres.	£
Ahmadabad	108	8 782	10 368	1 218
Kaira	1 675	15 754	8 301	3 019
Broach	20	768	—	—
Surat	1 641	17 848	10 872	4 725
Násik	889	39 490	27 641	14 929
Khandesh	94	11 584	8 945	5 580
Ahmadnagar	2	146	148	33
Puna	6	566	464	422
Sholapur	101	1 925	—	—
Sátára	1	90	89	34
Belgaum	1 055	15 999	7 768	2 363
Dharwar	3 150	110 176	61 678	11 511
Kaladgi	32	1 372	890	250
Kanara	226	24 512	—	—
Ratnagiri	3	1 105	1 105	499
Total	9 003	250 117	138 269	44 584

The Ekruk Tank.—The following are the data of the original project, which was carried out by F. D. Campbell, Esq., C.E.

Catchment area 141 square miles, minimum annual rainfall 12 inches; flood discharge of Adila River 37 000 cubic feet per second; a flood lasting five days gives 11 000 cubic feet per second; fall of Adila River 7 feet per mile, or 1 in 754.

Area of reservoir $6\frac{1}{3}$ square miles, maximum depth 60 feet.

Contents of reservoir 2 222 millions cubic feet $= 6\frac{1}{2}$ inches over catchment area.

Calculated maximum velocity over waste weir 10 feet per second. Waste weir discharge $250 \times 5 \times 10 = 12\,500$ cubic feet per second.

Total length of dam 7 200 feet, including 2 730 feet masonry. Maximum height of earthwork 72 feet, or 7 feet above flood line. Height of masonry 3 feet above highest flood, exclusive of 3 feet of parapet above.

Evaporation of 7 feet deep during eight months $= 750$ millions cubic feet.

Unutilised residue in bottom of tank 20 millions cubic feet.

It has three canals of discharge.

i. The lowest, perennial 28 miles long; its head is 20 feet above the level of the bottom of the tank, having a discharge of 44 cubic feet per second, an area irrigable from it of 25 square miles, 8 months, 912 millions cubic feet.

ii. The next for a four months' supply, 18 miles long, having a discharge of 42 cubic feet per second, an area irrigable from it of 21 square miles, 4 months, 435 millions cubic feet.

iii. The next for a four months' supply, 4 miles long, having a discharge of 21 cubic feet per second, an area irrigable from it of 10 square miles, 4 months, 217 millions cubic feet. The discharge of one four months' channel will be compensated by the mansun supply.

The duty of water for rice alone is fixed at 96 acres per cubic foot per second, and that for all crops together at 150.

Acreage under command, 35 840 acres.

The water rate for perennial crops is 16s., and that for one season crops 8s.

The calculated cost of the works was £100 937, including 15 per cent. for establishment; the probable gross revenue will be eventually £11 820, and the cost of maintenance £2 323, at

3 per cent. on the outlay; this will yield a net revenue of £9 491, or 9 per cent. on the capital expended.

The Tanks of Haidarabad are extremely numerous, the whole of the eastern portion of this state, which consists of black cotton soil, is thickly studded with them. They are all of the Madras type, similar to those of the neighbouring districts of Karnul and Ballari, and were in a very bad state of repair in 1870. There are also a few large artificial lakes, as, for instance, the Hosen Sagar near Sikandarabad, and traces of others, that at one time must have supplied a large amount of irrigation. There is unfortunately no information available as to their number or effective power, Haidarabad being an independent state extremely jealous of external interference. Latterly, however, about 1871, the Nizam had engaged the services of two or three English civil engineers, and it is hence very probable that he then commenced the repair and reconstruction of these tanks with the view of re-developing the irrigation of his province. Since then a permanent Public Works Department has been maintained, and though its efficiency has been much marred by native intrigue and parsimony, important results have been achieved. Details are not available.

The Tanks of the Madras Presidency are exceedingly numerous, and some of them are of immense size. They were made under the auspices of the Telingi rajahs. It is said that in the fourteen districts of Madras there are 53 000 tanks, having probably 30 000 miles of embankments, and 300 000 separate masonry works, weirs, and escapes, yielding a revenue of £1 500 000, and having a capital sunk in them of 15 millions sterling; yet in 1853 not one new tank had been made by the English, while a very large proportion of them had been allowed to fall into disrepair.

The Viranam tank, a very ancient work, in Tanjor, has an area of 35 square miles, and an embankment 12 miles long; it is still in full operation, and secures an annual revenue of £11 453.

The Chembrambakam tank in Chingliput resembles a large natural lake, its embankment is more than 3 miles long, and it has six waste weirs with a total width of 676 feet of escape; it supplies 10 000 acres of rice cultivation. This tank was enlarged in 1867, at a cost of £41 000. In 1882–83 its capital account had reached £62 454; and the revenue for the year

was £3 265, the irrigation being 12 763 acres of first crop, and 3 216 acres of second crop.

The Madrantakam tank in Chingliput yielded a gross return in 1872 of £1 697, and a net return of £1 607 on a capital outlay, probably spent in repairs or reconstruction, of £2 248.

The Kavari-pak tank in North Arcot is also of great antiquity; it is fed from the Paler River, and has an embankment nearly 4 miles long, reveted with stone along its entire length; it irrigates about 7 700 acres. In 1872 its banks were much damaged by an extraordinary flood, and some repairs were therefore made.

In the deltas of the large rivers of Madras there is a large number of tanks, the irrigation from which is mixed up with that from the deltaic canals in the official reports and returns. These have ceased to be storage works in the proper sense, having become distributing tanks; but there are many other large tanks that have not been transformed, about which there is no separate detailed information available.

In 1869, the author of this book was deputed by the Government of India to visit them and collect information, but was so soon transferred to other work that the results were small.

The irrigation from the Madras tanks in 1882 is given collectively in the following table:—

Madras Presidency.—Tanks and Minor Works of Irrigation, collectively.

Collectorate.	Imperial Works.			Minor Works.		
	Irrigation 1882–83.		Total Irrigation Revenue.	Irrigation 1882–83.		Total Irrigation Revenue.
	1st Crop.	2nd Crop.		1st Crop.	2nd Crop.	
	Acres.	Acres.	£	Acres.	Acres.	£
Ganjam ...	82 476	74	13 035	112 280	908	13 576
Vizagapatam ...	28 911	—	6 411	18 763	—	5 253
Godavari ...	32 326	895	4 480	31 146	525	3 168
Kistna ...	22 274	35	5 764	16 231	66	4 418
Nellur... ...	118 200	6 379	41 087	33 188	2 924	10 256
Kadapa* ...	53 584	16 600	24 162	123 211	31 224	41 145
Karnul ...	19 842	6 670	9 688	23 875	4 048	7 883
Ballari... ...	28 963	11 119	16 059	24 347	7 482	7 023
Anantapur ...	28 871	7 405	10 582	50 340	13 627	15 916
Chinglipat ...	198 661	35 676	50 999	126 933	17 867	27 532
South Arkat*...	212 534	20 382	65 727	142 843	15 306	42 203
North Arkat ...	96 477	22 844	33 937	141 611	54 162	50 177
Salem	21 926	19 932	10 475	75 246	67 926	25 086
Koimbatur ...	88 371	40 382	51 885	10 810	3 268	4 150
Tanjor* ...	40 750	2 603	10 017	32 089	1 809	6 014
Trichinopalli ...	67 572	26 107	22 572	64 049	20 332	16 863
Madura ...	89 298	48 530	24 580	68 547	26 399	12 942
Tinnevelli ...	129 369	104 777	103 198	68 881	37 134	37 080
Old Works ...	—	—	13 220	—	—	—
Total ...	1 360 405	370 410	517 887	1 165 389	305 006	330 686
Grand Total ...	2 525 794	675 416	848 563	—	—	—
Land Revenue	—	—	318 304	—	—	—
Total Revenue	—	—	1 166 867	—	—	—

* These figures are approximate.

The Tanks of Maisur are of native origin; they are exceedingly numerous, the whole country being amply supplied with irrigation by many series or chains of them; they are, however, owing to the configuration of the country, of small size, excepting in a few cases. They are in a very deteriorated condition, and have suffered greatly from silting up and want of repair and good management. The large amount of water utilised in tanks in Maisur, is indicated in the tables of the rivers of that province. It is unfortunate that the irrigated acreage due to tanks and anicuts are inseparably mixed in official records. Maisur, although it is a plateau elevated from 2 000 to 3 000 feet above mean sea level, has, with the exception of the Mulnad or rainy tracts of the Western Ghats, a small amount of rainfall, thus forcing water storage as an absolute necessity on its population; it, on the other hand, has the disadvantages of a sandy, and hence leaky soil, and comparatively steep surface slopes, the longitudinal slopes varying from 10 to 20 feet per mile in the flatter portions, and 60 to 80 in the steeper portions of the country, and more rapid transverse slopes; the former enhancing the cost of storage, the latter diminishing the breadth of irrigation from the channels of distribution. Stone is abundant, and is worked into rough forms, though too hard to be dressed for ordinary work. It is a gneiss of horizontal cleavage, which splits into sheets 3 to 24 inches thick, and 25 to 35 feet long, and is excellent for slabs and pillars, too hard to be dressed for ordinary work. For pitching, natural boulders are used, which are generally very round. Clay, on the other hand, is very rare; and lime is generally to be found only at great distances, and is hence often dispensed with in anicuts and overfalls, which are made to depend for stability on the size and position of the boulders.

Description of an average Maisur Tank.—Length of dam ¼ to 1½ miles; 18 feet high, 12 feet top breadth, 60 feet base. Front revetment of rough stone, with a batter of 1 to 2, its facing 1·5 to 3 feet thick backed with the same thickness of loose rubble; sluices 1 to 3 to each tank; section of vent 2½ feet × 2 feet, length 30 to 120 feet, form of section sometimes barrel-shaped, sometimes rectangular; they lead off from the lowest point in the tank. Inlet cistern 3 feet high, 6 feet square, outlet cisterns the same; plug pole and gibbed stones for orifice; escape weirs

1 to 4 for each tank, 30 to 300 feet wide, made of the largest stones, water front 3 to 9 feet deep; dam stones 3 feet apart, 4½ feet high, which when dammed give 2 feet more water; wing-walls 3 to 6 feet high, converging and afterwards diverging; tail paved either sloping for a long distance or horizontal; a lower stone wall is sometimes placed across the tail at some distance off to intercept some of the escape water, which is taken off by a channel.

Earlier Returns.—In 1853 there were 6 450 tanks in Maisur, of which 4 106 were large irrigating reservoirs, 13 737 small, and 8 609 unirrigating, *i.e.*, in a useless condition; giving about 1 effective tank per square mile in the gross; the area of Maisur being 27 269 square miles, of which 60 per cent. is under the tank system. In the seven districts of Kolar, where there are moderate conditions of rainfall, and no very large reservoirs, there were 3 611 tanks, of which 2 950 were irrigating, giving 1·07 tanks to a square mile, and an approximate average quantity of wet cultivation of 10 acres to each tank. In the comparatively rainless tract, comprising portions of six districts, on which the annual rainfall varies between 10 and 20 inches, there were 1 009 tanks, giving 0·31 irrigating tanks per square mile, and 2·5 acres of wet cultivation as an average to each tank. After that time a certain amount of money was spent in repairs. In 1866, however, the Executive Engineer of the Bangalur Division had reported that fully half the tanks under his charge were breached; in Chittaldrug 285, or one-third of the recorded number, were out of order; in Tomkur, 530 out of 1 124; in Shemugah, 2 496 out of 4 520; and in the Maisur Division, 705 out of 1 409. Hence, it appears, that there were in all about 1 500 larger tanks requiring repair at a rate of £300 each, and 3 000 smaller at £150, and that a total outlay of £900 000 was necessary to put them in good order.

In 1872–73 as many as 249 tanks were breached. The Irrigation Department of Maisur is now dealing with the matter gradually, by bringing the tanks up to a certain standard of repair, and then handing them over to the superintendence of the tax collectors; by these means it is hoped that the tanks of Maisur will be economically brought into good condition.

Among the very large reservoirs requiring special notice, are the Naggar Sulikerrai, on the river of that name, which has a

margin of about 40 miles, and an embankment 1 000 feet long, 84 feet high, and 600 feet breadth of base; the Maddak tank on the Vedavatti, whose embankment is 1 220 feet long, and 90 feet high, having a breadth of base of 660 feet; and the Motitalao, on a feeder of the Lokani, having an embankment 117 feet high, 225 feet long, and a breadth of base of 375 feet. These are in specially favoured situations, between two hills guarding the outlets of large valleys. The proposed Mauri Kunawai and Kumbarkattai reservoirs have similar sites.

Later information in 1882–83 is not available, as the province is now under native administration as an independent state.

Maisur Tanks.—Catchment Areas.

River Basin.	Total Length of main Rivers with their Affluents.	Drainage Area unintercepted by Tanks.	Drainage Area intercepted by Tanks.	Total Area of each Catchment Basin.	Proportion of whole Area under the Tank system.
	Miles.	Sq. miles.	Sq. miles.	Sq. miles.	Percentage.
I. Kistna River ...	611	4 814	6 217	11 031	56
II. Palar	47	—	1 036	1 036	100
III. Penner	167	334	1 946	2 280	85
IV. Pennar	32	222	1 319	1 541	85
V. Kavari	646	5 526	5 769	11 295	51
VI. Western Coast rivers	103	1 181	0	1 881	0
Totals for Maisur and Kurg	1 606	12 777	16 287	29 064	56
Deduct for Kurg ...	—	1 795	—	1 795	—
Total for Maisur only ...	1 516	10 982	16 287	27 269	60

Maisur Tanks.—Irrigation and Outlay.

Period.	Under wet and Garden Cultivation.	Expenditure on Repairs other than the Astagram Channels.	Average yearly Outlay.
	Acres.	£	£
From 1837–38 to 1841–42 ...	1 705 150	47 018	9 404
" 1842–43 " 1846–47 ...	1 849 759	43 225	8 645
" 1847–48 " 1851–52 ...	2 087 929	58 644	11 729
" 1852–53 " 1856–57 ...	2 160 309	70 021	14 004
" 1857–58 " 1861–62 ...	2 169 040	80 762	16 152
25 years' total outlay	—	299 670	11 987
25 years onchannel repairs ...	—	57 537	2 301
25 years on tanks only	—	242 133	9 686

Storage Waterworks of Indian Cities.

Bombay.—*The Vahar Reservoir, by Henry Conybeare and Walker.*

Bombay was the first of the Indian cities to carry out for itself waterworks on a modern system, and call in the aid of English civil engineers to design and superintend their execution.

In 1854 Mr. Henry Conybeare determined that the Vahar basin, in the valley of the Goper, was adequate to the collection and storage of all the water that would be required for Bombay for some years; the works were therefore confined to the formation of one artificial lake, and their execution entrusted to Mr. Walker, as Resident Engineer, in 1856. The catchment area was 3 948, and was capable of being extended by catch-water drains to 5 500 acres; the annual rainfall 124 inches, of which it was calculated that six-tenths or 74·4 inches would be available, would in these cases supply 6 600 millions, or 9 000 million gallons. The storage capacity allowed was 10 800 million gallons; deducting from this the loss from evaporation, which at 6 inches per month for the eight dry months of the year, would amount to 1 000 million gallons, the available supply would be 9 800 millions. As the annual rainfall on the gathering grounds greatly exceeded the annual consumption of Bombay, it was evident that the water would continue to rise in the lake from the commencement to the end of the rains, or for three months, leaving only nine months' consumption to be provided for. Hence, the reserve allowed in the lake was equal to 9 800 − 3 700 = 6 100 million gallons, at an allowance of twenty gallons per head per day for a population of 700 000 during nine months, and was thus nearly equal to two years' supply.

When filled up to the level of the waste weir, the maximum depth of the Vahar Lake is 80 feet; it covers an area of 1 394 acres, and stands 180 feet above the general level of Bombay. The three dams by which the water in the lake is impounded, are respectively 84, 42, and 49 feet in extreme height, and 835, 555, and 936 feet in extreme length at the top, and they altogether contain the following quantities as totals: earthwork 406 066 cubic yards; puddle, 55 059; broken stone under

pitching, 1 983 cubic yards; and pitching, 53 617 square yards. The top width of dam No. 1, which carries a road, is 24 feet, and that of the two others 20 feet; the inner slope of all three embankments is 3 to 1, the outer $2\frac{1}{2}$ to 1; the embankments were specified to be formed in regular layers less than 6 inches thick, watered, punned, and consolidated. The puddle walls are 10 feet wide at the top, and batter 1 in 8; the trenches for foundations were excavated through the surface rock and past all surface springs into the solid basalt below; the slopes and tops of the dams were covered with 12 inches of stone pitching over 12 inches of broken stone.

The waste weir is 358 feet long, and has a top width of 20 feet, faced with ashlar. The water is drawn from the reservoir through a tower, provided with four inlets, at vertical intervals of 16 feet, having a diameter of 41 inches, and provided with conical plug seats faced with gun-metal—the plugs being suspended from a balcony, and worked by cranes at the top of the tower. The inlet in use is surmounted by a wrought-iron straining cage, covered with No. 30 gauge copper-wire gauze, and fixed to a conical ring, fitted into the inlet orifice in the same manner as the plugs, and equally capable of being raised or lowered at pleasure: the strainer has a surface of 54 square feet. The strainer is so affixed to the cage as to admit of its being changed in ten minutes from a boat, and a plug substituted for the cage. At the bottom of the inlet well, and exactly over the entrance to the main, is another conical seat, into which a similar straining cage, having a surface of 90 square feet of No. 40 gauge copper-wire gauze is inserted. The objects of this arrangement were to utilise the whole head of water, including that due to the depth of the lake, which would have been lost had the water been strained at the outside foot of the dam; and to avoid the use of heavy sluice-valves, in positions in which it would be difficult to get at them. Without this, the utmost head obtainable would have been insufficient for a distribution by gravitation alone. No filtration arrangement nor sludge-pipe were considered necessary.

The supply main traversing the dam is 41 inches interior diameter, and its metal $1\frac{3}{4}$ inches thick: it is laid in a level trench excavated in the rock and filled with concrete: the portion traversing the puddle trench is supported on ashlar set in

cement, puddled to a depth of 6 inches, and then arched over with four rings of brick in cement; two teakwood washers being affixed transversely on the pipes to prevent any water from passing between the pipes and the puddle. At the sluice-house, situated at the outside foot of the dam, the large main, 41 inches in diameter, bifurcates into two mains, each 32 inches, which continue for a distance of nearly 14 miles to Bombay. The supply is distributed through the town by branch and street mains in the usual way: the hydrants are self-closing, and of a design that admits of their closing either with or against the water pressure, the counterweights being adjusted to the resistances at the various levels of the town: the sluice-valves, 32 inches diameter, are so constructed as to be capable of being closed or opened under the severest pressure, with a very trifling exertion of force; the smaller valves are on Underhay's system, which admits of the removal of the valve seat and valve, without disturbing the laying of any portion of the mains. The water is delivered under a pressure of from 165 to 180 feet.

The actual delivery of water commenced in March, 1860. The original estimate of these works was £250 000; their cost, including interest, was £655 000. The result was a supply of excellent water to Bombay of 8 000 instead of 9 800 million gallons daily, bringing in an annual revenue of £38 000. At present, in 1873, when the population has increased to 800 000, the supply per head amounts to only 10 gallons daily, and an additional supply is required. Various projects, having this object in view, have been proposed by Mr. Russell Aitken, Captain Hector Tulloch, and Mr. Rienzi Walton, C.E., municipal engineers, and a very large amount of time has been spent in discussing them.

MADRAS.—*The Cholaveram and Red Hill Reservoirs.*

For Water Supply and Irrigation by W. Fraser.

The original estimate of the works was as follows:—

	£
i. A dam across the Cortelliar Stream	8 170
ii. A channel with the head and other sluices, bridges, and other requisite works, for 8½ miles from the dam to Cholaveram tank	2 206

	£
iii. The enlargement of this tank by raising its embankments 18 feet	15 239
iv. A channel $2\frac{3}{4}$ miles from the Cholaveram to the Red Hill tank, with sluices, bridges, and other works	6 596
v. The enlargement of this tank by raising its embankments 15 feet	11 793
vi. A channel from Red Hill tank to the Spur tank in Madras, with sluices, bridges, and other works ...	2 803
Sundries, compensation, superintendence	13 348
	63 693

In consequence of alteration of design and increase of rates the subsequent revised estimate amounted to £104 264.

The dam as erected was 469 feet long, and $6\frac{1}{2}$ feet high at crest, resting on a solid foundation 4 feet deep, on the top of a double row of wells 9 feet deep, which were carried down to a clay stratum; the body wall was made of laterite. The head sluices consisted of ten vents 5′ × 8′ high, having piers and abutments 3 and 5 feet thick, built on 9 feet wells and 3 feet foundation connected with the dam; the sill of sluices is 6 feet below the crest of the dam; these works are made of dressed gneiss and laterite. Supply channel $8\frac{1}{2}$ miles long, inclination 2 feet per mile, bottom breadth 30 feet, slopes $1\frac{1}{2}$ to 1, berms 15 feet each, the ordinary excavated soil to be used for embankments in low places; intended supply 2 700 million cubic feet in 35 days.

Cholaveram Lake dam as existing 1 mile long, extended and raised 18 feet on hills of laterite and gravel; escape weir 200 feet long made to discharge 94 million cubic feet, or a quantity equal to the total capacity of lake up to sill in twenty-four hours, with a depth of discharge on sill not exceeding 12 inches; this quantity is assumed, because these tanks have been filled in twenty-four hours of mansun in extreme cases. Supply channel in laterite, which can be utilised, section as before, fall 3 feet per mile.

Red Hill Lake embankments 9 000 feet long, only slightly extended, as the ground rises rapidly, and raised 15 feet. In reconstructing the embankments, the old work is stepped and the new earth laid in thin layers, sloping inwards, the puddle

wall is carried up simultaneously, outside which is a 12-inch layer of gravel and stones, and beyond that 18-inch stone pitching. Surplus weir 400 feet long, to discharge and keep the surface down to 2¾ feet above sill: two irrigation sluices, and the head sluices aid in this; these are similar to those for the Cholaveram Lake.

Bridges—14 road bridges; 7 foot and cattle bridges; 12 siphon culverts for under drainage and irrigation.

Data of Supply.—The Cortelliar gives 450 millions of cubic yards in 30 to 40 days of mansun; its small summer channel is perennial. Drainage area 770 square miles; the above mansun yield of which is only 6½ inches over the surface, or about one-fifth the downfall. Two other streams also yield 540 million cubic feet per annum, which is also intercepted. The Cholaveram Lake formerly held 91 million cubic feet, but when raised will hold 983 millions cubic feet. The Red Hill Lake formerly held 553 millions cubic feet, and now 2 754 million cubic feet; the two together 3 737 million cubic feet; this, after deducting the amount of water to which the Mirasidars have a right, will leave 2 522 million cubic feet; of this amount 162 millions will be used to irrigate 8 571 acres of rice, at 1 890 000 per acre, yielding £600 at 14s. per acre, and 891 millions for water supply. Assuming that the population of Madras will increase from 170 000 to 500 000, and will require a supply of 20 gallons per head daily, their wants will not exceed 594 million cubic feet per annum. The distribution of the town supply from the Spur tank forms a separate municipal undertaking; the municipality of Madras agreeing to pay 1 rupee per 27 000 cubic feet of water taken from it.

The original rates of work per cubic yard were—earthwork of all sorts, 2¾ to 4 annas; puddling, 6 to 8 annas; revetment, 8 annas; stone work complete, 3 rupees to 3 rupees 4 annas; thus, quarrying and squaring, 1 rupee 8 annas; cartage, 2¾ miles, 1 rupee; building, 8 annas. These rates were afterwards increased.

The capital outlay up to the end of 1871–72 was £104 772, but some further sums were spent during 1872–73; from which it would seem that the Madras waterworks were then nearly in perfect working order; the income and cost of maintenance up

to 1872–3, was £222 and £2 911 respectively; and during 1872–73, £1 516 and £667.

These waterworks, which Mr. Fraser was not allowed to complete, have been particularly unfortunate. Some earthwork in the tank-dam, in 1869, was done quite at random, so that prospective failure seemed inevitable, in the author's opinion.

In later times, after mishaps, the works have been altered and extended. In 1882–83 the capital expenditure was £147 296, and the irrigation revenue £2 100 on about 10 400 acres of crop, including first and second crops. This covers more than the working expenses.

NAGPUR.—*The Ambajheri Reservoir, constructed by Mr. A. Binnie.*

The name of the projector of this scheme, which is an enlargement of a native tank, is not mentioned in the official records: it was chosen from among other projects for the supply of Nagpur, by Mr. Binnie, in 1869, and laid before Government in two forms—one combining irrigation, and the other without; the second was adopted.

Data.—Population, 84 000, catchment area 6·6 square miles, bare and basaltic, having an annual rainfall 40·73 inches, mansun rainfall 37·52 inches. Proportion run off in an average mansun 0·43, minimum 0·268, maximum 0·6.

The evaporation is based on Conybeare's measurements at Vahar, Bombay, which give 2·5 feet in eight months of dry season, or $\frac{1}{8}$ inch daily, hence allowance is made for 3·5 feet in eight months as a maximum for Nagpur. The rate of silting determined from observation to be 2·5 feet in 80 or 90 years = 0·375 inches annually. Supply allowed 7 gallons per head daily, and as this is all wanted nearly at one time, the pipes are made to deliver 15 gallons per head daily. There is no filtering arrangement, but strainers of copper-wire gauze are used, being fixed in wooden frames in the inlet tower. The siphon is 2·5 feet in diameter, length 185, rise 15, fall of 2 feet to overcome friction: air pipe 3 inches diameter. The siphon joints are turned and bored, flanges packed with wood, bolted and fastened with hoop iron, bolts and washers. The maximum head is 78 feet or 34 lbs. per square inch, hence the pipes are tested to 130 lbs. per square

inch. The formula used for the discharge of pipes is Young's Eytelwein, $v=50\sqrt[3]{\left(\frac{dh}{l+50\,d}\right)}$. There are scouring valves at low points. The embankment is in layers 12 inches thick, inclining inwards 1 in 6, retentive clayey material alone used; its surfaces of hard material, covered with 12 inches of rough hand pitching; its slopes are outer $1\frac{3}{4}$ to 1, inner 2 to 1; its foundation is stepped and benched. The escape weir is of basalt rubble, its sill of angle-iron $3 \times 3 \times \frac{1}{2}$ welded and bolted to blocks. The waste watercourse is 18 feet broad at bottom with slopes 1 to 1. The main pipe is carried on walls of rubble, or in a bed of concrete 3 feet thick, stepped into the embankment; in the valve house it is laid in concrete. Pipes above 13 inches diameter to have wide sockets, caulked with spun yarn, and lead driven in with caulking tools; those of less than 13 inches turned and bored, fixed with Roman cement. All pipes to be tested under pressure by hammer 7 lbs. weight. Angus Smith's process applied to all pipes inside and out after fitting. Distributing pipes to bear on solid ground, in trenches 4 feet to $2\frac{1}{2}$ feet deep, filled and rammed.

The puddle wall in the centre of the dam is 5 feet wide on the top and 10 below, and 30 feet high, made in layers of 8 inches.

The above project, drawn up in detail in 1869, was sanctioned in April, 1870; the contemplated irrigation being deferred. The estimates amounted to £32 535; the reservoir was opened in October, 1872, but the distribution was not carried out by that time. The reservoir has a top surface of 370 acres, and a storage of 257·5 million cubic feet, of which 240 millions, or 1 500 million gallons, are available.

The cost of excavating the puddle trench, including pumping, was £2 368, at the rate of 1s. per cubic yard; the cost of puddle, £6 659, at 4s. per cubic yard; the cost of embankment, in 1 foot layers, rammed and watered, was £4 277, at $5\frac{1}{2}$d. per cubic yard; the rates for pitching were from 5s. to 10s., and for turfing, 2s. per 100 superficial feet; the total cost of the outlet, including straining-tower, foot-bridge, well and valve house, was £2 893, and that of the escape weir, £821; the rates for ashlar, basalt, rubble, and concrete being from 27s. to 54s., from 10s. to 16s., and 8s. per cubic yard.

The distribution source is a public one, the water standards being placed 100 yards apart along the streets. The main pipe was 4 miles long and 1·1 feet in diameter, and the distribution pipes 10 500 yards long and 1 foot in diameter; the pipes were delivered in Bombay at £7 5s. per ton, and in Nagpur, at £11 14s. The works were completed within the estimate, and a supply of 15 gallons daily per head can be maintained in years of extreme drought.

AKOLA.—*The Akola Reservoir.*

A Project for combined Irrigation and Water Supply of Akola, by L. D'A. Jackson, Executive Engineer for Irrigation in Barár.

The proposed works consist of—

i. A reservoir formed on the Morna River by a masonry dam and earthern embankments east and west of it.

ii. An irrigation channel 5 miles to the first watershed, and 3 more to the third watershed to the east of the river, and irrigation channels 15 miles to the west of the river.

iii. Filter beds, drinking and bathing basins, with a fountain at the town gate of Akola, with pipes to it $1\frac{1}{2}$ miles in length.

1. *Masonry Dam* 625 feet long, extreme height 36 feet; area of section of superstructure down to 30 feet $0·3H^2$, and of foundation below that $21h$; strengthened by buttresses 50 feet apart from centre to centre; the wing-walls rise to 8 feet above the sill level and revet the embankments, which are 8 feet wide at top, slopes 2 to 1 and 3 to 1, and have a section 10·5 H; length of eastern wing 2 751, western 9 057 feet.

2. *Reservoir*, extreme length and breadth about $2\frac{1}{4}$ miles, area of water-spread 2 500 acres: of which 1 000 are under cultivation, and on which there are only a few small huts.

Contents available for perennial irrigation, cubic feet			411 055 831
Available for town supply	"	...	58 427 360
Waste or standing water	"	...	3 843 139
Total contents		...	478 326 330

Beside this, there will be available for mansun irrigation in season of extreme drought at least five times the above total from the perennial flow of the river.

3. *Channel.*—Section 45 square feet, slope 1 in 3 000, discharge 100 cubic feet per second below original ground level in section. In eastern channel 8 super passages in each, having section of 60 square feet and discharging 150 cubic feet per second; 8 road crossings; 2 under passages through embankments, being 2 feet pipes enclosed in masonry culverts. In western channel 9 super passages, 12 road crossings, and 2 under passages. The small trenches of distribution to be made by the landowners, aided, if necessary, by loan.

4. *Town Supply.*—Main pipes, 4 inches in diameter, having a fall of 1 in 500, and each discharging 0·25 cubic feet per second. Beds and basins excavated in rock, with walling above ground. Filter bed and bathing basin each 50 feet square and 10 feet deep. Drinking basin octagonal having the length of each side 40 feet, and having a jet in the centre, the water for which will be purified by a filter on the ascending principle passing through perforated walling and tiles, then large and small pebbles, sand, and magnetic carbide.

5. *Supply of Reservoir.*—Catchment area 220 square miles, minimum downpour 12 inches, of which 6 inches run off, give 3 066 million cubic feet in a year of drought, and fill the reservoir six times. The extreme flood discharge over the weir sill, using a local coefficient of 12 for the formula $Q = 12 \times 100\ (N)^{\frac{3}{4}}$, = 67 200 cubic feet per second; and assuming a flood velocity of 13 feet per second, this gives a flood section of 5 170 square feet The waterway allowed is $8 \times 125 = 5\ 000$ square feet; the measured flood sections are in support of the sufficiency of this.

Irrigation.—Land under water command on the east bank 45 square miles, west 30 square miles; total 75 all fertile; the perennial supply for irrigation during the eight dry months is 410 million cubic feet, or 19·5 cubic feet per second, which at a duty of 200 acres will irrigate 3 900 acres. The mansun irrigation supply for four wet months exceeds any demand that is likely to occur; the probable maximum acreage for this will be about half the irrigable area, or 20 square miles on one bank and 15 on the other, being in all 35 square miles or 22 400 acres; the channel of supply is designed to carry sufficient to irrigate the total area of 75 square miles.

Cost of Works and extension on the west bank	...	31 301
Compensation and Road diversion	...	1 000
Establishment and contingencies 20 per cent. ...	...	6 869
		£39 170
Probable return, when the works are fully developed:—		
Perennial, *i.e.*, 8 months, 3 900 acres at 14s. ...	...	2 730
Mansun, *i.e.*, 4 months, 22 400 acres at 4s. ...	...	4 480
		7 210
Collection, repairs, establishment, 8 per cent.	...	577
Result, net return on capital of £40 000 at 16½ per cent.		£6 633

Or, deducting capital spent in town supply, a result of 19 per cent. on the outlay on the capital spent in irrigation, independently of the water rate charged to the town.

Water Rate.—The classification of water rates for various crops is that adopted on the Bari Doab Canal, but the rates themselves are doubled, as the cost of labour in Barar is double that in the Bari Doab. Hence the rates assumed for Barar are :—1st class, sugar-cane, £1 4s.; 2nd, rice and garden produce, 19s.; 3rd, all ordinary field crops, not elsewhere mentioned, 10s.; 4th, all millets, pulses, and grass crops, 6s.; 5th, a single watering, 3s. These may be expected to yield mean rates of 14s. and 4s. at the least, as it is most probable that sugar-cane will be extensively grown; all sugar being now imported into Barar.

Reclamation and Protective Works.

The sole Reclamation Works of large extent in combined India and Burma at present consist in the Irrawaddi Works, under Robert Gordon, a Civil Engineer of special experience.

The Irrawaddi Reclamation Works. — The delta of this enormous river, consisting of valuable agricultural land liable to periodic inundation uncontrolled by any efficient protection, afforded an excellent site for reclamation works. Before 1862 a few light embankments were thrown up by voluntary labour, under the guidance of unskilled officials, mostly British magistrates and tax collectors, and *employés* of the Indian Public Works Department. A high flood in 1861 swept the delta and brought ruin to the agriculturists; it also directed the attention of the Indian Government to the need of direction, and of the expenditure of money on a large scale. In 1862 Colonel Short, an officer of experience on works of embankment in Bengal, was deputed to report on the project of generally embanking the Irrawaddi in the delta in permanence. The name of the projector is not officially mentioned; but the plans under which the works begun are named as those signed by Colonel Short. These works were carried out by Mr. Bennett until the close of 1868; they consisted mostly of banks about 16 miles below Saiktha, near the town of Myanoung, having for an object the control of the floods at the junction of the Patashin River, and the recovery of about 250 square miles of land. A dam near Kyangheen, above Myanoung, designed and executed by Mr. Fennessy, C.E., was made in 1864; the length of bank being then in all 10½ miles. It appears that these banks were generally from 1½ to 2 feet above high flood, and were never nearer than 100 feet to the river edge. In 1868 a high flood breached much of the unfinished work; and the question of general design was reconsidered. It had been the original intention to close the Nawoon or Bassein branch, which was gradually closing itself: it was now determined to leave it open, and the project hence took a new form. This practically consisted in embanking both the Nawoon and the Zaloon

branches, from the head of the delta (above Otpho) along their courses to the S.W. and S.E., in addition to the upper works for the control of the main river above, between Kyangheen and Otpho. From this time, 1868-69, the project departed from the protective type, and became one of more pure reclamation on an immense scale. It virtually consisted in the recovery of the whole of the upper part of the delta, as permanently useful agricultural land, by means of banks on the inner or deltaic sides of the two branches.

The area of this from Otpho or Thambyading down to near Bassein on one branch, and to near Shuayloung on the Zaloon branch, is about 2 400 square miles, roughly involving about 180 miles of single embankment, besides accessory works. Such a design involved a thorough study of the whole of the hydrologic conditions of the Irrawaddi, as well as extensive surveys.

About this time Mr. Robert Gordon was entrusted with the whole management of the works, having before executed parts of them. His laborious examination and studies of the river, and the execution of the project are deserving of the highest respect. His voluminous report on the Irrawaddi should be perused by all interested in hydrology.

The first four miles of the Nawoon embankment were executed in 1869; operations were then suspended till 1871. In 1871-72 the first 25 miles were completed; they afterwards progressed at the rate of about 15 miles yearly until, in 1875-76, about 75 miles of it (to Toboo) were finished. On the main Irrawaddi Channel (or Henzada Zaloon branch) work commenced in 1869, some few miles of bank were made, and Henzada was enclosed; in 1872 the bank was extended about 14 miles to Zaloon; and in 1875 it had reached Donabyu. The alignment is generally 300 to 400 feet from the edge of river; in some cases it was more economic to follow the higher ground, in others to cut across bends, and save in length. As to section, the earlier works varied greatly; but their top widths generally were from 4 to 6 feet, the height 5 to 10 feet, and the slopes various. In later works a uniform top width of 14 feet was adopted for convenience of road traffic, and the height uniformly fixed at 3 feet above recorded flood marks on the Zaloon branch, and at 2 feet minimum on the Nawoon branch similarly; the slopes $2\frac{1}{2}$ to 2 to 1 on ordinary soil, but more on light sandy or sliding clayey soils.

The cost of the banks was about £1 700 per mile; in some parts £1 000, and in others as low as £656; the whole of the main works, about 110 miles constructed since 1818, have cost on an average £840 per mile.

In 1877 a high flood damaged the old Kyangheen embankment, but the Myanoung embankment did not suffer. On the more recent works, the bank at Zaloon was breached on the 15th of August, 1877. In 1879 a breach occurred in high flood at the 29th mile of the Myanoung embankment, but this was due to neglecting a leak. In October, 1879, when the official record ends, the proposal to continue the Donabyu embankment as far as Shuayloung, had not been sanctioned.

As to projects for further reclamation in the neighbourhood of the Irrawaddi River, these are various and are necessarily on a large scale. The entire confinement of the Irrawaddi between banks, from Suiktha to Thambyading, and along the Zaloon branch from Thambyading to Yandoon, would reclaim a very large strip of submersible land on the east bank, nearly up to the Rangoon Prome Railway. A similar treatment of the Nawoon branch to near Bassein would . less effective.

In 1882–83 the capital on May in the western embankments amounted to £305 000; the net revenue was £46 289, and the working expenses £8 733.

*Protective Works.**

Such works, intended for the protection of towns or special localities from the encroachment of large rivers, are generally very restricted, and to be successful are also costly. Besides, they require skilled engineering of the highest order in addition to energetic management; a change of engineers proves fatal to such schemes that require the personal care of the special individual capable of carrying out his own intention in the work. It is hence useless to attempt to give details of means and materials employed in the more successful works of this class; the engineer will hence be simply mentioned.

* The term "protective works" is sometimes applied to mere irrigation works in Indian official records.

Lahor Protective Works.—The spurs on the stream, 200 feet wide, which were effective in diverting it, were carried out by Lalla Kanhya Lall.

Phillawur Protective Works.—The Phillawur bridge was protected from the encroachment of the Satlaj by Mr. Anderson, C.E.

The Gandak Works.—These were carried out by Mr. Stony, C.E., who gives an account of the works and the success achieved; he also mentions that temporary works of this sort can only achieve a temporary success; that intermittent attempts may fail immediately they are discontinued. There is no such thing as leaving a river safe for any long time after turning it.

The Indus Works.—In 1861, after the failures of several engineers to divert the river Indus from destroying the town and cantonment of Dera Ismail, the method adopted and carried out by a very young engineer of hardly two years' experience in hydraulic matters, was successful, and resisted the floods of the year 1862. This success was specially remarkable, as the works were carried on in spite of violent opposition of the civil magistrate and his police, who repeatedly attempted to seize the labourers, boatmen and boats. Certainly they were beaten off from time to time, and the works were continued and saved; but this energetic self-sacrifice was followed by burglary, and a plot to murder the youth at night, in which the civil authorities connived by refusing help. Further self-defence was followed by a deplorable but legal attempt to murder the youth; this perjured evidence culminated in his expulsion. In 1863–64 the works were entrusted to others, and failure resulted. Other failures followed, with much expenditure of money. In 1875 fresh works were undertaken which achieved merely a partial success.

The Satlaj Works.—These were carried out by Mr. Graham, C.E., in 1874, and were successful in guiding the river through the Adamwahan bridge, thus saving the bridge.

Madras Presidency.—The protective works, as officially classed, seem merely to include temporary works for closing breaches in tanks and in canal banks; they are thus works on a small scale generally; the expenditure of the whole Presidency being, in 1882–83, only £6 425.

IRRIGATED CROPS.

NORTH-WESTERN INDIA.

The Panjab was formerly a fully irrigated country traces of its thorough canalisation exist everywhere; it was formerly, perhaps in the time of Porus, the granary of India, and the most civilized province.

It has since become an arid country, comparatively depopulated. Perhaps there has been a climatic as well as a political change; the Indian desert may formerly have been one-fourth of its present size; and the rivers of the Panjab may have given nearly double their present supply of water.

At present the Panjab is in a state of partial recovery; canals and irrigation exist over perhaps one-tenth of its formerly irrigated area. From a modern view, and as regards irrigated crops, it is virtually a mere extension of the North-West Provinces of North-Eastern India, in which the crops that suffer most from drought exist but very partially. Hence the following accounts of the crops of those provinces will serve as a basis without recapitulation. (*See Crops, North-east India.*)

Noticing, therefore, by way of comparison: the larger cereals are magnificent in the Panjab, gram and lentils also; but, apparently, the lesser millets and the lesser pulses are purposely neglected, and rice is naturally rare. The breadth under oil-seeds is comparatively small; green fodder crops are also small in extent, bhúsa or chopped straw being more used.

Among the special crops (dyes, drugs, spices, and fibres) cotton alone figures largely; indigo and sugar-cane are relatively in very small proportion; tobacco and opium are grown in small quantities; capsicum is largely grown.

In the returns of canal irrigation there are a few crops peculiar to the Panjab though of small extent; these are mehndi, a rose dye from the Himalayas; also munj kana, cherāl, zīra, but these may be mere local names.

The crops of the Western Jamna canal are grown partly within the Gangetic basin, nominally in the Panjab province, but actually out of the Panjab; they may hence mislead as a whole.

THE WATERING SEASONS OF IRRIGATED CROPS IN THE PANJAB.

Crop.		Time of Sowing.	Time of Reaping.	Earliest date of Watering.	Latest date of Watering.
On the Western Jamna Canal.					
Kharif	Sugar-cane	Feb. to April	Nov. to Feb.	1 March	28 Feb.
Kharif	Cotton	March to June	Sept. to Dec.	1 March	31 March.
Kharif	Rice	May to July	Sept. to Oct.	1 May	31 Oct.
Kharif	Great Millet	June to Aug.	Sept. to Oct.	1 June	15 Sept.
Kharif	Maize	May to Aug.	October	1 June	15 Sept.
Rabi	Wheat	Oct. to Dec.	April to May	1 October	31 March.
Rabi	Barley	Oct. to Dec.	April to May	1 October	31 March.
Rabi	Gram	Sept. to Nov.	April to May	1 October	31 March.
On the Bari Doab Canal.					
Kharif	Cotton	25 April 25 June	15 Sept. 13 Dec.	11 April 25 April	25 Sept. 20 Oct.
Kharif	Rice	26 May 25 June	15 Sept. 4 Oct.	13 May 30 June	28 Aug. 15 Sept.
Kharif	Sugar-cane	8 Feb. 11 April	5 Oct. 8 Feb.	11 Jan. 9 Feb.	28 Aug. 15 Sept.
Kharif	Indigo	25 April 15 Sept.	25 June 15 Nov.	12 June 28 July	21 Aug. 21 Sept.
Kharif	Great Millet	12 May 26 June	15 Sept. 20 Oct.	12 May 11 June	27 Aug. 21 Sept.
Kharif	Maize	do.	do.	do.	do.
Rabi	Barley	15 Oct. 27 Dec.	11 April 5 May	15 Sept. 14 Oct.	19 March.
Rabi	Gram	15 Oct. 29 Oct.	31 Mar. 16 April	27 Aug. 29 Sept.	Not after sowing.
Rabi	Wheat	15 Oct. 29 Oct.	31 Mar. 16 April	15 Sept. 14 Oct.	24 March.

THE PANJAB.—*The Value of an Acre of Produce in* 1872.

	On the Western Jamna Canal, 1872.	Irrigation	Produce per acre.	Market value in 1872.
		acres.	lbs.	£
	Sugar-cane—*Ikh*—Saccharum officinarum	44 531	2 000	7·70
	Garden produce, various	50 158	--	8·
	Rice—*Dhan*—Oryza sativa		1 920	3·30
Dyes & Fibres.	Cotton—*Kapas*—Gossypium herbaceum	96 129	720	3·60
	Hemp—*San*—Crotalaria juncea ...	305	200	1·25
	Indigo—*Nil*—Indigofera tinctoria ...	6 489	20	1·15
	Safflower—*Karar*—Carthamus tinctorius	—	120	3·
	Turmeric—*Haldi*—Curcuma longa ...	—	—	—
Oil-seeds.	Sesame—*Til*—Sesamum Orientale ...	25	160	0·80
	Pigeon Pea—*Toria*—Cajanus indicus ...	642	640	1·5
	Mustard—*Saru*—Sinapis campestris ...	—	400	1·
	Linseed—*Alsi*—Linum usitatissimum ...	—	120	0·60
	Waternuts—*Singara*—Trapa bispinosa...	—	6 400	8·
Drugs & Spices.	Tobacco—*Tambaku*—Nicotiana tabacum	1 271	2 800	0·90
	Poppy—*Posta*—Papaver somniferum ...	6	240	3·00
	Coriander-*Dhania*-Coriandrum sativum	863	5 600	2·30
	Halaun—Phaseolus rostratus	—	5 600	2·30
	Ajwen—Ptychotis ajwen	—	400	2·
	Fenugreek-*Methi*-Trigonella fœnugrœcum	23	400	2·
Cereals.	Great Millet—*Jowar*—Holcus sorghum	4 203	1 680	2·70
	Italian Millet-*Kangni*-Panicum italicum	43	1 600	2·60
	Spiked Millet-*Bajra*-Penicillaria spicata	347	1 520	2·5
	Millet—*Chena*—Panicum miliaceum ...	96	1 520	2·4
	Maize—*Makki*—Zea mays	893	1 600	2·5
	Wheat—*Gehun*—Triticum vulgare ...	93 599	1 520	3·20
	Barley—*Jau*—Hordeum cœteste ...	3 602	1 120	1·5
	Oats—*Walayati jau*—Avena sativa ...	19	1 200	2·4
Pulses.	Common Gram-*Channa*-Cicer arietinum	7 796	1 400	2·25
	Lentil—*Masur*—Ervum lens	1 679	400	0·60
	Urad—Phaseolus—Mash	410	1 440	2·80
	Mung—Phaseolus mungo	4	1 440	1·80
	Moth—Phaseolus aconitifolius	77	1 440	1·80
Fodder.	Lucerne—*Sinji*—Medicago sativa ...	313	3 200	2·
	Grass—*Ghas*—Triticum repens... ...	46	4 800	0·75
	Great Millet—*Charri*—Holcus sorghum	193	3 200	0·40
	Miscellaneous	unknwn.	—	—
	Fallow	6 300	—	—
	Single Waterings...	10 485	—	—
	Total	554 190	—	—

PANJAB.—*Value of Irrigated Crops per Acre.*

Bari Doab Canal in 1882–83.

	On the Bari Doab Canal.	Kharif.	Rabi.	Total.	Produce per acre.	Value of Produce.	Value of Crop. per acre.
		Acres.	Acres.	Acres.	Lbs.	£	£
	Sugar-cane ...	12 241	4	12 245	2 000	81 636	6·7
	Garden produce ...	289	284	573	—	3 787	6·6
	Rice	39 744	39	39 783	1 600	90 931	2·2
Cereals.	Wheat ...	—	156 054	156 054	1 520	474 404	3·0
	Barley ...	—	1 726	1 726	1 120	2 417	1·4
	Maize ...	25 664	—	25 664	2 240	71 859	2·8
	Great Millet ...	21 307	—	21 307	1 280	28 409	1·8
	Italian Millet...	412	—	412	1 600	1 319	3·0
	Chena Millet...	—	106	106	1 200	133	1·2
	Mixed Grain...	—	3 079	3 079	1 120	5 389	1·7
Pulses.	CommonGram	—	13 086	13 086	1 360	22 247	1·6
	Lentils ...	—	648	648	480	346	0·5
	Fodder and Grass	2 679	21 795	24 474	—	22 898	0·5
Oil-seeds.	Til	959	—	959	170	639	0·6
	Toria... ...	5	130	135	640	253	1·8
	Linseed ...	—	34	34	160	23	0·7
	Sarsun ...	—	850	850	720	1 912	—
Fibres, Dyes, & Drugs.	Cotton ...	29 353	1	29 354	720	88 063	3·0
	Hemp ...	358	—	358	400	716	2·0
	Indigo ...	1	—	1	—	1	1·0
	Turmeric ...	5	—	5	960	32	6·4
	Safflower ...	—	$\frac{1}{8}$	$\frac{1}{8}$	86	1	3·0
	Poppy ...	—	450	450	320	3 602	8·0
	Tobacco ...	150	52	202	2 000	2 527	12·5
	Vegetables ...	1 295	956	2 251	—	8 103	3·6
	Orchards	2 098	1 451	3 549	—	23 428	6·4
	Miscellaneous ...	7 814	4 365	12 179	—	18 336	1·5
	Fallow	544	1 302	1 846	—	—	—
	Single Waterings...	1 553	731	2 284	—	—	—
	Total	146 471	207 144	353 615	—	953 466	—

THE PANJAB.—*Canal Plantations in* 1872.

Detail of Trees chiefly grown.		Western Jumna Canal. Number in 1872.	Bari Doab Canal. Number in 1872.
Local Name.	Botanical Term.		
Kikar or *Babul* ...	... Acacia arabica ...	394 718	173 124
Shisham ...	... Dalbergia sissu ...	119 611	451 566
Shahtut Mulberry ...	Morus alba ...	72 526	54 458
Shahtut China	... Morus tatarica (Mulberry)	2 130	—
Tun ...	... Cedrela tuna	33 789	31 853
Jaman ...	... Sizygium jambolanum	17 214	—
„ ...	... Prunus Padus ...	—	4 887
Bakain ...	... Melia azedarach ...	16 764	—
„ ...	... Melia sempervirens ...	—	5 966
Sirus ...	... Acacia speciosa ...	16 870	47 292
Gular ...	... Ficus cunia	11 755	—
Jand ...	... Acacia leucophlœa ...	7 205	—
Jand ...	... Prosopis spicigera ...	—	11 551
Nim ...	... Azadarachta indica ...	7 152	—
Bans ...	... Bambusa stricta ..	4 911	—
Amb ...	... Mangifera indica (Mango)	3 774	—
Pipal ...	... Ficus religiosa ..	2 004	—
Phulai ...	... ...	—	71 710
Plum ...	... ...	—	16 735
Phagara ...	... Ficus caricoides ...	—	9 760
Mudasu ...	... ...	—	6 178
Aliar ...	... Dodonæa burmaniana	—	4 850
Beli ...	... Zizyphus flexuosa ...	—	4 689
Sembal ...	... Bombax heptaphyllum	—	8 013
Miscellaneous of 80 descriptions		—	
Miscellaneous trees of 83 descriptions ...		—	—
	Total of all sorts ...	809 779	955 567

Experiments in Watering Crops of Wheat and Rice on the Bari Doab Canal.

(*By* E. C. Palmer, C.E., *in* 1871.)

The average of the experiments made and tabulated show that an average depth of 0·24 feet on the whole surface, represents a thorough watering of the average soil of the district under consideration, and for sandy soils 0·31 feet, and the amount of water necessary for an average watering of one acre, is $0·24 \times 43\,560 = 10\,454$ cubic feet.

Wheat in a dry season requires five waterings; the first, for preparing the land for ploughing, at 10 500 cubic feet, and four for the standing crop of 8 000 cubic feet, give 42 500 cubic feet in all necessary for each acre of wheat.

Rice requires ten floodings; the amount of water necessary for each flooding is the amount necessary to saturate the soil, the average of which, given above, is 0·24 feet, together with 0·50 feet of standing water: or in all, 0·75 feet in depth over an acre represents the quantity of a flooding, or $0·75 \times 43\,560 = 32\,670$ cubic feet; and the quantity necessary for a crop of rice is, therefore, 326 700 cubic feet.

The land under consideration principally consisted of holdings on an average of 52 acres, requiring 22 acres of Kharif, and 30 of Rabi irrigation; for such a farm an irrigating outlet or pipe 0·4 feet in diameter, working under a head of 0·4 feet, was found sufficient; the discharge being 0·3323 cubic feet per second, and allowing the farmer eight days to prepare his 22 acres of Kharif ploughing, and eleven days for the 30 acres of Rabi ploughing. As the best season for this purpose lasts about six weeks, and the outlets are allowed to flow for eight days in the month at the utmost, this arrangement allows twelve days of constant flow during that season; and thus a single pipe, irrigating only 2·7 acres per day of twenty-four hours for ploughing, or 5·4 acres of standing crops, is sufficient for all the purposes required in keeping up the irrigation of a holding of 52 acres.

These data apparently support the amount mentioned in official returns as the average supply per acre given on the Bari Doab Canal, 44 000 cubic feet; the latter probably including also single waterings over a certain amount of acreage.

THE WATERING SEASONS OF IRRIGATED CROPS IN THE DERAJAT, 1872.

Crop.	Usual time of Sowing.	Usual time of Reaping.	Earliest date of Watering.	Latest date of Watering.	Remarks.
On the Indus Inundation Canals.					
Cotton	1st to 15th June	Oct. and Nov.	1st to 15th May	Until reaping in Oct. and Nov.	Cannot be sown earlier on account of hot winds
Rice	May	15th to 30th Aug.	1st to 15th May	15th Aug. to 18th Sept.	Sown in March, watered from wells, and transplanted in May.
Indigo	1st to 15th May	1st year August, 2nd year 1st to 15th Sept.	1st year 8th May, 2nd year in April	End of Aug.	Indigo for seed gets a watering in September.
Jowar ... ... Bajra	June July	15th Sept. 15th to 30th Sept.	15th to 31st May 1st to 15th April	15th to 30th Aug. 1st to 15th Sept.	These crops require at least one watering before ploughing and two after sowing.
Barley ... Gram ... Wheat ...	20th Sept. to 31st Oct.	20th Mar. to 15th April	July	September	Require 1, 2, or 3 waterings before sowing, and sometimes one after sowing, but not often.

N.B.—The inundation of the Indus commences in May.

BHAWALPUR.—*Irrigated Crops in* 1866–67.

		Centals.		Acres.	Produce per acre in Centals
Kharif harvest.	Sugar-cane	2 400	on	329	7·30
	Great Millet	280 000	„	58 270	4·81
	Sesame	5 600	„	2 391	2·36
	Spiked Millet	160 000	„	33 900	4·72
	Rice...	640 000	„	137 860	4·64
	Mung, Muth and Mash ...	11 200	„	3 574	3·13
	Cotton	9 600	„	2 218	4·33
	Indigo	4 800	„	22 207	0·21
	Vegetables	—		not given	—
Rabi harvest.	Wheat	600 000	on	72 500	8·28
	Barley (Jau)	22 400	„	3 708	6·04
	Gram...	6 400	„	2 132	3·00
	Maithra and Peas	not given	„	1 879	—
	Mustard and Ussun	3 200	„	987	3·24
	Nanghi and Sanwak	not given	„	997	—
	Tobacco	560	„	383	1·46

English Centals of 100 lbs. are used above.

Note.—A Bhawalpur beegah is given as ½ acre; a beegah = 10 khanas; a khana = 16½ × 16½ ft. = 21 780 sq. ft. The local maund is taken as an Imperial maund of 40 ser.

RAJPUTANA.—*Crops Irrigated from Tanks in* 1882–83.

	Acres.		Acres.
Sugar-cane	31	Gram	694
Garden produce ...	53	Mung, Moth, Urad, Chaula and Kulath	230
Vegetables	327	Til	144
	411	Cotton	1 821
		Tobacco	5
Wheat	3 816	Poppy...	680
Barley...	9 149	Miscellaneous ...	58
Maize	10 068		3 632
Rice	49		
Great Millet	56		
Spiked Millet ...	36		
Mixed Grain	5 290	Grand Total	32 507
	28 464	Estimated Value ...	£54 196

SIND.—*The Watering of Crops.*

The following details were compiled by Mr. Robert Brunton C.E., in 1867. He states that in the Government Gardens the mode of lifting water by "wheel and bullocks" is very clumsy and expensive. On the right bank of the Indus the irrigation from the canals is effected by flow; on the left bank the land is high, and there are 18402 nars (two-bullock wheels) and 29921 hurlas (one-bullock wheels) constantly employed. The canals here have their beds seldom more than 7 feet below the average level of the land; and the independent wells vary in depth from 10 to 20 feet. A "nar," with four men and four pairs of bullocks, can irrigate 11 acres of cultivation, the total cost per acre of watering is £1·5. A "hurla" is worked by two men and two pairs of bullocks, and keeps 6 acres watered.

A sufficient flooding is estimated at 3 inches of depth, or 10800 cubic feet to an acre; the necessary number of floodings per crop, is

Crop.	Period.	Number.
For wheat, barley, and rape	4 months	4
For bajri	" "	5
For jowari	" "	6
For sugar-cane	12 months	52

Mr. Brunton remarks that the Spanish method is far superior and less costly than the Indian one, and points out that by the adoption of an improved "noria" with a small tank as an adjunct, and an improved system, the cost of watering might be reduced to less than a tenth of £1·5 per acre; while the advantage to the province of freeing two-thirds of the men and bullocks would enable three times the extent of land to be brought under cultivation.

North-Eastern India.

North-west Provinces.—The following are the agricultural conditions, mostly according to Messrs. J. B. Fuller and J. F. Duthie in 1882.

Nearly half the province consists of land actually cultivated, while about a quarter more is cultivable. The land revenue and cesses amount to about four shillings per cultivated acre; the rental is double the revenue. Two-thirds of the population are supported direct by agriculture, out of a whole population varying from 466 to 978 per square mile of cultivated area.

The alluvial soil of the plains varies little generally; the distinctive terms used, are these—

Clay soil	*Matyár*
Very stiff clay	*Dokra*
Poor clay	*Dhaukar*
Pure sand	*Bhur, balua*
Saline yellowish and saline reddish clays	*Usar*
Light yellowish unfertile soil ...	*Rankar*
Loamy soil...	*Domat*
Special loams	*Rosli, sewai and seolah*
Light reddish loam	*Pilota, pilia, saigun*
Stiff black loam or cotton soil ...	*Már*
A paler cotton soil	*Kābar*
A grey loam	*Parwa*

In some places the *usar* tracts amount to 4 per cent. and in others 11 per cent. of the whole area.

Kankar (carbonate of lime) occurs, both in its nodular form and in blocks, in beds a few feet below the surface, scattered throughout the province. The *usar* salt efflorescence (*reh*) (sodic sulphates and sodic carbonates chiefly) and *kankar* are formed under the same natural conditions of an impermeable subsoil concentrating the action of formation. *Nona mitti* is the nitrate of potash efflorescence on soil near villages, and on mud walls. *Khāri pani*, the brackish water from wells, contains nitrate of soda; it is of great manurial value to growing crops but checks germination.

Manure.—Most of the cattle-dung is used as fuel. The

refuse of vegetable matter and ashes find their way to the soil, but these are not systematically arranged and applied, excepting near large towns. The belt of land (*gauhán* or *bára*) close to a village is highly manured naturally by the inhabitants; the next belt (*manjha*) is manured from the muck heap every third year; the outer lands (*barha* or *pálu*) are never manured, and hence are taken at a lower rental. *Nona mitti* is used as manure for tobacco crops; *Khari pani* is also used generally. Crushed bones are not used, and indigo refuse is most commonly used as fuel for glass making, though in Bahar it is used as manure.

Tillage.—Some of the ploughing is mere scratching of the surface with a very light plough drawn by weak cattle; but repeated ploughings, generally eight, even twelve to fifteen, and sometimes twenty, prepare an excellent soil for the valuable crops. The common ploughs vary from 18 to 50 lbs. in weight. There is also the *nágar* plough, weighing 320 lbs., drawn by eight bullocks, which tears up the soil to a depth of 18 inches (the Indian as well as the English cubit). Levelling and breaking up clods is done by the heavy flat log (*henga, mai patela* or *páta*) drawn by two pairs of bullocks; a lighter one is termed *maira*. A roller (*lakkar*) formed of a trunk of a tree is also used in sugar-cane cultivation.

There is on an average one plough bullock to every 4½ or 5 acres cultivated; buffalos are seldom used for ploughing.

The Seasons.—The *kharif* season is the summer and autumn, from April to September inclusive, in which tropical crops are grown: rice, maize, cotton, millets, &c. In the earlier three months of *kharif*, termed *zäid*, melons and common millet are grown; these ripen in June. At the end of May or beginning of June indigo and maize are sown in irrigable land. Ploughing begins actively at the beginning of the rains at the end of June or beginning of July; and is followed by sowing cotton, rice, great millet and spiked millet; the land for *rabi* crops is also ploughed at the beginning of the rains, and reploughed at least four times in July and August.

Sugar-cane, termed a kharif crop, is exceptional; it is sown from January to April, and cut in the following cold season.

The *mansun* rains begin about the end of June, and are over

by the end of September generally; breaks in the rains may spoil the maize and rice crops, and irregularities in the rains, early or late, may ruin any of the *kharif* crops, except, perhaps, the common millet.

The *rabi* season, or cold weather season, from October to March inclusive, is the period of crops of temperate climates: garden and vegetable produce, wheat, barley; the cabbages, &c., brocoli, turnips, carrots, láhi and rāmdána are sown about the middle of September; but the sowing of the more important *rabi* crops including the cold weather cereals, begins in the middle of October and continues till the middle of November. The dates of harvesting vary much, but all of them are off the fields by the middle of April.

The *winter* rains are light, and fall about the end of December generally; the *rabi* crops are partially dependent on them, as well as on the moisture in the soil retained from the *mansun* rain; but the winter rains are very shifty. The nature of the subsoil hence has an important bearing on these crops.

Irrigation.—The annual rainfall of the region, from 2 to 3 feet may be concentrated in the *mansun* of three or four months, and this may be deficient, early or late, or with long breaks, or in excess. Each one of these five causes of ruin to the crops has to be guarded against; four of them are those of deficiency at certain times; hence the need of irrigation. The source of irrigation from wells, tanks, and canals, in these provinces is chiefly not local but Himalayan rainfall.

The irrigated area is at present about one-fourth of the cultivated area. The percentage of the irrigated area, according to sources of irrigation, are, from wells about 56 per cent., from canals 24 per cent., and the remainder from other sources, streams and tanks.

Well sinking involves much risk, as the well is generally a failure if a clay stratum is not met at a moderate depth, or if the well is sunk through numerous or continuous layers of loose sand. Wells more than 60 feet deep to water are considered unprofitable. A spring well, tapping a water-bearing stratum under a clay stratum, of the depth of about 30 feet, is the desired object; a mere percolation well, ending in loose sand and dependent on collected drainage, is seldom of

much use. The lifting appliances used are chiefly the leather bucket, holding 12 to 25 gallons, and, in fewer cases, the (rahát) chain of pots, and the lever and counterpoise (dhenkli); also the simple wheel with two balanced pots (charkhi). The watering effected in a day varies from one-eighth to one-sixth of an acre in wells from 40 to 20 feet deep.

Streams and tanks.—The locality in which irrigation from tanks is practised is the Banáras division, where the rainfall is greater and the soil more retentive; also on the border of the Central-Indian hill ranges, where are many magnificent tanks made by the Chandel princes, as appendages to temples. In the Sub-Himalayan tract temporary dams and watercourses from streams are used for irrigation.

The lifting appliance used is the swing basket of bamboo (beri) or of leather (bauka); the economic lift is 3½ feet; and two-fifths of an acre can be irrigated per day: the maximum single lift is 5½ feet; for a total lift of 10 to 15 feet they are worked in stages.

Canal irrigation.—A large portion of the area now irrigated from canals of sure supply was formerly irrigated from precarious wells dependent on rain supply. The more valuable crops are now raised on land close to some distributary channel, from which a timely supply is certain. In other cases, where the land is farther off, there are the risks of not gettng a timely supply of water to a crop, as the period of taking water is fixed for each village, and as the demand for water on land higher up may be great enough to monopolise the supply for some time. Another source of irregularity is that greatest of all curses, official caprice.

The under-officials that control the distribution of the water are often afflicted with lofty but unjust principles. Woe to the land when the servant is master! This is an evil almost inseparable from large concerns with divided interests. Apparently, in such cases as these, the fair remedy would be that the individual suffering should impose a fine on the authorities collectively, and that a fund be set aside to meet these demands.

The comparative cost of three waterings to a wheat crop under various modes is thus given by Mr. Fuller:—

Mode of Supply.	Lift.	Daily Irrigation.	Wear and Tear and Interest.	Bullocks.	Men.	Total.
	Feet	Acre.	s.	s.	s.	s.
Kacha Well, worked by lever lift	10	$\frac{1}{8}$	1	—	12	13
Kacha Well, worked by a pair of bullocks	30	$\frac{1}{5}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$7\frac{1}{3}$	$17\frac{1}{3}$
Pakka Well, worked by a pair of bullocks	30	$\frac{1}{5}$	$6\frac{1}{2}$	$5\frac{1}{3}$	$7\frac{1}{3}$	$19\frac{1}{3}$
Tank and swing basket	4	$\frac{1}{4}$	0 Price of water	—	9	9
Canal and swing basket	3	$\frac{1}{3}$	3	—	7	10
Canal flush irrigation	0	3	6	—	—	6

Cost of Cultivation per Acre.

Each operation.	Shillings.	Each operation.	Shillings.
Ploughing ...	1·50	Cleaning	0·75
Harrowing, &c. ...	0·25	Watering dues ...	variable
Sowing drilled ...	1·75	„ lift $4\frac{1}{2}$ feet ...	2·25
Weeding (kharif)...	3·	„ distributary ...	0·25
Weeding (rabi) ...	1·50	Preparing land ...	0·50
Watching (kharif) ...	1·50	Cost of seed }	variable
Reaping	variable	Cost of manure }	variable
Threshing ...	6·00		

This apparently amounts to about £1 per acre, up to £1 5s. per acre for one set of operations.

The holdings are small, from 3 to 9 acres, worked by the occupier and his family. When rent is paid in kind, it varies from one-third to half the produce. The outturn of crops by average cannot be stated with any degree of confidence.

The chief crops grown in the North-west provinces, from an average of three years from 1878 to 1880, bore the following proportions to the total cropped area :—

Wheat 13·4; Rice 11·3; Barley and Gram 9·5; Great Millet and Arhar 6·4; Barley 6·3; Great Millet 5·7; Gram 4·8; Wheat and Barley 4·2; Spiked Millet 4·1; Wheat and Gram 3·8; Cotton and Arhar 3·6; Maize 3·0; Sugar-cane 2·5; Cotton 2·2. Almost all the rest less than 1·0 per cent. of each.

NORTH-WESTERN PROVINCES.

	Botanic Term.	Indian Names.	Sown.	Cut.
Common Cereals.				
Wheat	Triticum sativum	*Gehun, Gandum.*	End of Oct.	In Mar. or Apr.
Barley	Hordeum vulgare	*Jau.*	October	In Mar. or Apr.
Oats	Avena sativa	*Jai, Walayati jun, Javi.*	As barley	
Maize	Zea mays	*Maki, Makai.*	Mansun break	In July and Aug.
Rice	Oryza sativa	*Dhán, Baranj.*	Bet. Jan. & July	Bet. May & Nov.
The Millets.				
Great Millet	Sorghum vulgare,	*Juár, Junri, Cholam.*	Mansun break to Nov.	
Spiked Millet	Penicillaria spicata,	*Bájra, Lahra, Kambu.*	do. or later	
Italian Millet	Setaria Italica	*Kángni, Tángan.*	Mansun break to Sept.	
	Eleusine coracana	*Mandwa, Makra, Ragi.*		
	Panicum miliaceum	*Chena, Chirwa, Varagu.*	March	May
	Panicum frumentaceum	*Sānwan Samei* Sacred Millet	Mansun break.	End of Aug.
	Panicum psilopodium	*Kutki, Mijhri.*	June	October
	Paspalum scrobiculatum	*Kodon, Koda.*	Mansun break	October
Legumes.				
Com. gram	Cicer arietinum	*Channa, Nakhud.*	From mid. Sept.	April
Lentil	Ervum lens	*Masur.*	Rabi crop, like peas	
Paralytic pea	Lathyrus sativus	*Kassar, Kasári, Tiuri.*	Rabi crop, like peas	
Common pea	Pisum sativum	*Mattar.*	End of Sept.	March
Field pea	Pisum arvense	*Desi mattar, Chattar.*	do.	do.
Pulses ...	Phaseolus mungo	*Múng.*	Mansun break	October
	Phaseolus radiatus	*Urad, Másh.*	do.	Aug. and Oct.
	Phaseolus aconitifolius	*Moth.*	do.	do.
False french bean	Vigna catiang	*Lobia, Rausa, Sonta.*	Like Mung	

Soil, Cultivation, and Produce.

Heavy loam (domat); follows cotton, maize, or a fallow; on manured sites close to villages. Eight ploughings. Seed 100 to 140 lbs. per acre. Irrigated once before sowing, thrice during growth. Liable to rust, smut and bunt. Yield, unirrigated 720 lbs.; irrigated, 1 200 lbs. per acre. Exports 100 000 tons.

Light soil, unmanured. Four ploughings. Seed 100 to 120 lbs. per acre. Two waterings; liable to smut. Yield, unirrigated 800 lbs.; irrigated, 1 280 lbs. per acre. Straw in weight $1\frac{1}{2}$ times yield in grain.

Corresponds to barley; but is grown for fodder; requires irrigation. Yield, 800 to 1 440 lbs. per acre; improved by manure; requires better soil than barley does.

Manured soil. Four ploughings. Seed 12 lbs. per acre. Two waterings; plants banked; much watching. Yield 1 120 lbs.

Stiff clay; even usar. Two to six ploughings, or hand dug to six inches. Seed 80 lbs. to the acre; banked fields; transplanting is optional. Subject to green fly in August. Yield, unhusked 800 to 1 280 lbs.; $\frac{2}{3}$ of this is grain.

Loam. Two ploughings; 10 to 24 lbs. of seed per acre. Generally mixed crop. Yield 640 to 890 lbs. grain, and large quantities of fodder. Liable to bunt and to poisonous insect *bhaunri*. Much watching.

Light, poor soil; no manure or irrigation. Two ploughings. Seed 6 lbs. per acre. Liable to bunt, mildew; suffers from excess of rain, and from extreme drought. Yield 490 to 560 lbs.

Manured; good soil. Suffers much from birds. Yield 320 to 420 lbs. per acre. Straw nearly useless as fodder.

Light soil, even grows on shingle. Seed 10 lbs. to an acre. Suffers from heavy rain. Yield 400 to 1 120 lbs.

Light soil. Seed 10 lbs. to an acre. Irrigated from wells. Precarious. Yield 560 lbs. Straw useless as fodder.

Light soil, grows even on saline. Seed 10 lbs. to an acre. Suffers from blight and excessive rain. Yield 720 lbs.

Grown on the poorest lands. Average yield 160 lbs. per acre.

On poorest soil. Seed 12 to 20 lbs. to an acre. Yield 800 to 960 lbs. unhusked. Suffers from insects.

On heavy clay. 80 to 100 lbs. Unirrigated. Suffers from frost or cold. Yield 640 lbs.

Also on any soil as a mixed crop with wheat or barley; irrigated; also with rape and linseed.

On all soils. 80 lbs. to an acre. Produce, unirrigated 640 lbs.; irrigated 960 lbs.

On very heavy clay; in mire and rice stubble. Very hardy. The grain induces paralysis.

Heavy soil. 120 lbs. per acre. Yield, unirrigated 560 lbs.; irrigated 800 lbs. Chaff same weight.

Correspond to common peas, but are less prolific.

On light soils; mixed crop with cotton or millet. It withstands drought, and does not impoverish soil.

On heavy soil, mixed with cotton or millets. Suffers from mildew. Resembles mung.

On the worst land as a sole crop; gives a heavy outturn. Yield 640 lbs. Mixed with bājra.

Mixed crop with cotton or millets. If alone it yields 400 lbs. per acre.

	Botanic Term.	Indian Names.	Sown in.	Cut.
Pigeon pea	Cajanus indicus	*Arhar, Thúr Dál.*	Mansun break	Apr.
(Climbing bean)	Dolichos Lablab	*Sem, Sembi.*		
—	Cyamopsis psoralioides,	*Guar, Khulli, Kudra.*	Mansun break	Oct.
Oil Seeds.				
—	Eruca sativa	*Dúan, Taramira.*	Sept. to Nov.	April
Rape	Brassica campestris	*Sarsun (pila & kāli)*	(Accomp. its mixed crop)	
(Toria)	Brassica campestris	*Tori, Toriya, Khetiya.*		Cut in Feb.
(A mustard)	Brassica juncea	*Rai, Lahi.*		Cut in Mar.
Sesame	Sesamumindicum	*Til, Jinjili.*	Mansun break	Oct.
Castor plant	Ricinus communis	*Rendi, Eranda.*	Just before Mansun.	March
Linseed	Linum usitatissinum	*Alsi, Tisi.*	Rabi crop	
Gourds, &c.				
The cucumbers, gourds, melons, pumpkins, &c., are extremely numerous.			April.	June
Dyes, Drugs, Fibres, &c.				
Sugar-cane	Saccharum officinarum	*Ikh, Ukh.*	February	January
Indigo	Indigofera tinctoria	*Nil.*	Before or at Mansun break.	Aug. or Sep.
Safflower	Carthamus tinctorius	*Kusumbh, Kar, Karar.*	Oct.	Feb. & Apr.
Poppy	Papaver soniferum	*Posta.*	Oct.	March
Tobacco	Nicotiana tabacum	*Desi, tambaku.*	July	Feb.
Rustic Tobacco	Nicotiana rustica	*Kalkattia tambaku.*	Nov.	Apr.
Cotton	Cossypium herbaceum	*Kapās, Ban Bári.*	Mansun break.	Oct to Jan.
Hemp	Cannabis sativa	*Bhang.*	May	Sept.
San hemp	Crotalaria juncea	*San, Sania.*	Mansun break	Oct.
Roselle hemp	Hibiscus cannabinus	*Ambári, Patsan, Pitwa, Lattia San.*	Various	

Soil, Cultivation, and Produce.

Any soil, as mixed with cotton or millets. Killed by frost. Leaves and stalks are valuable.

As a green vegetable, not for grain; as a border crop, but never alone.

A green fodder crop; also for grain. Yield 800 lbs. per acre.

Any soil. Mixed with gram, barley or bejhar, or in cotton fields; for food oil and lighting oil.

Mixed with wheat or barley. Suffers from aphides. Oil is ⅓ weight of seed. 160 lbs. per acre.

Sole crop. Alone it yields 320 to 480 lbs. per acre.

Mixed with wheat, barley or peas. 240 lbs. per acre. Oil is ⅓ weight of seed.

Light soil, rough cultivation. Seed 16 to 24 lbs. per acre. Ruined by heavy rain. Yield 400 lbs.

Border crop to cotton and sugar-cane. Seeds yield ⅓ the weight in oil. Cut down after a year.

Heavy soil; also in rice stubble. Yield 480 to 800 lbs. per acre of seed, for oil; unirrigated and irrigated.

In any light soil, without any care. Exceedingly prolific in islets, river beds, &c.

Good loam, manured; after a year's fallow. Manure 6 to 8 tons per acre; ploughings 12 to 25. 20 000 cuttings per acre; 3 hoeings, 2 weedings. Yield 1 600 to 2 400 lbs. of sugar per acre. Annual export 80 000 tons.

Loam, or light sand; after sugar-cane or cotton. Not manured. Ploughings 4. Seed 16 lbs. to acre. Waterings 2 to 6. Weedings 2. Yield 6 400 lbs. per acre.

Light soil. Seed 20 to 25 lbs. Often mixed crop; irrigated. Suffers from insects. Yield 60 lbs. dry florets.

Manured good loam. 6 to 8 tons per acre. Irrigated with nitrates and saltpetre dressing. Ploughings 8. Seed 3 lbs. per acre. Waterings 5. Weedings 3. Suffers from caterpillars. Yield 20 lbs. opium per acre.

Highly manured loam; irrigated with nitrates and saltpetre dressing. Ploughings 8 Transplanted 6 inches apart after three months. Waterings 8. Suffers from frost and grey mildew. Yield 800 lbs. tobacco.

Good loam, with manure or not. Seed 8 to 12 lbs. per acre. Ploughings 4. Weedings 2 to 4. Little watering or none. Good drainage. Suffers from grubs and caterpillars. Yield 100 to 200 lbs. clean cotton.

Highly manured soil of any sort. Seed 60 lbs. to acre. Yield, charas 6 lbs.; fibre 320 lbs. Seed 70 lbs.

Light soil, not much manured. Ploughings. 2. Seed 80 lbs. to an acre. No weeding or watering. Yields 640 lbs. of clean fibre (*arjha san*) per acre.

Border crop with indigo or with cotton. Fibre used for sacking. Yield 50 to 300 lbs. fibre per acre.

NORTH-WEST PROVINCES.—*Varieties of Crops according to Fuller.*

Wheats.—Some of the chief varieties and terms used are—

Daudi or *dudia*, a variety of soft white wheat.
Paighambari.—A variety, round berried.
Badha.—Term for hard white wheats.
Pissi.—Term for soft red wheat.
Kathia or *lallia.*—Term for hard red wheat.
Mundia.—Term for beardless wheats.

A mixed crop of wheat with barley is termed *gojai;* a mixed crop of wheat with gram is *gochana*, or *birra.*

Barleys.—The six-rowed variety, hexastichon, is most common; the two-rowed variety, distichon, is rare; a sub-variety of distichon, termed gymnostichon or *paighambari* or *rasuli*, of Arabian origin, also exists; its flower-scales drop off in threshing; it yields as much as 1 720 lbs. to the acre.

A mixed crop of barley with gram is termed *bejhra.*

Oats.—This is a crop of English introduction. The old method was that an Englishman supplied seeds for the agriculturists to grow on soil prepared for a barley crop, but more frequently for fodder (three cuttings) than for the grain.

Rice.—The chief classes are three—

1. Tall, feathery, protruding ear; thin yellow husks.
2. Shorter and more erect; less protruding; thick husk, red or yellow.
3. Commoner sorts, short stems, partly enclosed ear; husk dark or black.

Varieties of the first class are *naha, bánsmatti, bānsphal, jhilma.*

Varieties of the second class are *seondhi* and *sumhára.*

The chief and commonest variety is *sathi*, a rapid crop grown in sixty days.

The wild rice is termed *passari* or *phasahi*, and a sub-variety of it as *tinni.*

A rice crop sown broadcast, and grown without transplanting, is termed *munji;* these are the commoner varieties, sown at mansun break, termed *bhadoi* or *kuari*, according as the crop is cut in August (*bhadon*), or September (*kuār*).

A rice crop, transplanted two or three weeks after sowing, and of the superior sort, is termed *aghani*, being cropped in November (*aghan*).

Hot weather rice, termed *boron* or *jethi*, is sown in January, transplanted in February, and cut in May.

Unhusked rice is termed *dhān*; husked rice, *chāwal*, and rice straw, *piāl*.

Great Millet.—Very numerous varieties, both white-grained and red-grained. The three chief are—

1. The double-seeded, with two grains to each husk.
2. The short variety, with stalks only three or four feet.
3. *Cháhcha.*—A variety in which the grain is completely covered by the husk, and suffers less from birds.

Juār is grown for green fodder, *chari*, or for its dry stalks and leaves, as dry chopped fodder, *karbi*; also for its grain, the staple food of the inhabitants.

Spiked Millet.—The two distinct varieties are—

1. Bajrā, with large grain of greenish colour.
2. Bajrī, with smaller grain of reddish colour.

The small Millets.—The varieties of these have received little attention.

Pulses.

Gram.—The chief classes of varieties are—

1. The large-grained, markedly reddish grain.
2. The small-grained, light-brown grain.
3. The Kabuli, very large grain, white; resembling the Garbanzos of Spain and the Spanish colonies of South America.
4. The black grain, corresponding to the Portuguese small beans, and those of Brazil, but smaller. In all sorts; the tops are cropped as a vegetable, *sag*, and the straw (bhúsa) is excellent as food for cattle.

Lentils are vetches, *viciæ*, of the same tribe as gram, during growth resembling them much; but the leaves of lentil are alternate, and nearly sessile, while those of gram are in pairs, and serrate. *Kassar* is also a vetch; its seed is a slightly-flattened pea.

Múng.—The ordinary mung has green seed and dark green leaves, but there are two other varieties having yellow seeds and black seeds; the bhúsa is excellent for cattle. *Urad* is a variety

of mungo, with dark-brown large seeds, rather long, and hairy yellowish-green leaves. *Moth* is different in many respects, and has small light-brown seeds, oblong in form. *Lobia* is also different, having small foliage and reddish purple flowers, while *mung*, *urad* and *moth* have yellow flowers; but all are of the tribe Phaseolus. These Indian pulses are greatly superior to the small millets, from not impoverishing the soil, from their hardiness against drought, from the excellence of their *bhúsa* for cattle, and of their seed for human food.

The pigeon-pea is a phaseolus, having many varieties; *Sem* also, but this is grown as a vegetable for its green pods, not for grain. *Gudr*, or *khulti*, of the tribe Galegeæ, having large trifoliate leaves, is excellent as green fodder as well as for its dry pulse.

Oil-seeds.

The oil-yielding Brassiceæ are very numerous in variety, under the four classes given in the general list; the varieties require a botanical expert of high order.

Sesame yields the sweet oil used over the greater part of India. There are two varieties, one with black seeds, *til;* the other with white, *tili.* It is not grown in rainy tracts, where the oil-yielding makua tree (*Bassia latifolia*) abounds, and a crop of til might suffer.

Castor oil plant is grown for lighting oil and lubrication; the stalks for thatching.

Linseed is grown for its oil and for the oilcake, not for fibre. The common linseed is brown, but there is also a white-seeded variety, especially useful for colour-mixing, which is also generally superior.

Other Crops.

Sugar-cane.—Edible cane is eaten raw and as a sweetmeat; its principal variety is termed *paunda*, and has a soft, thick, juicy stalk.

The chief varieties of the non-edible cane, grown for producing sugar, are (1) *dikchan* or *barokha*, a cane ten feet high, soft and very juicy; (2) *agholi* or *matna*, five or six feet high, yielding less but thicker juice; (3) *chin*, a tall, hard, reddish cane; (4) *dhor*, a short, white, hard cane. The two latter are grown on inferior land, with less care.

Indigo.—There are several wild varieties of this legume, as well as the cultivated ones; the only two mentioned as classified are the *indigofera atro-purpurea* of the Himalayas, wild; and the *indigofera anil*, cultivated in Southern India. The *asarpi* unirrigated indigo system forms the old staple crop in this province. It is sown at mansun break, and reaped in September. The roots are left, and a ratoon crop (*khunti*) is grown from the roots in the following rains. Under the new *jamowa* system the *chaiti* indigo is sown and cropped a month earlier; the soil is ploughed and prepared for a rabi crop. This necessitates irrigation, but enables two crops to be had from the land in the year. When a seed-crop is wanted under the jamowa system, the roots are left for a ratoon seed-crop in December. Indigo is not a popular crop, as it involves the factory system, carried out under unpleasant driving.

Safflower.—The varieties are—1st, the wild safflower of the Panjab, *carthamus oxyacantha*; 2nd, the ordinary thorny-leaved safflower; 3rd, a smooth variety, *murilia.*

Poppy.—There are numerous varieties of the white poppy, which in this province is preferred to the malwa or red purple poppy. In the Panjab the same preference is shown for the ragged-edged white poppy.

Tobacco.—Nicotiana tabacum is probably of Arabian introduction, corresponding to Latakia; it has pointed leaves growing on the stem, or sessile, and pinkish headed flowers. *Nicotiana rustica* is that of Turkey and of the Philippines, with stalked and rounded leaves rather crumply, and flowers pale yellow and short in the tube. The modes and seasons of culture vary much; apparently it might grow at any time, except during frost, as it is otherwise a sure crop, not attacked by insects. *Sáwani* tobacco is sown between July and August, in small seed-beds, with wood ashes; transplanted in October, and cut in February. *Asárhi* tobacco is sown in November, planted out in February, and cut in April or May. The cultivation is of a high order, and expensive—about £5 per acre. All the risk is in the curing of the tobacco, which requires perpetual skilled superintendence.

Cotton.—This hibiscus forms the staple crop, with little apparent variety, under the widest appellation of bári, its other names not indicating varieties. These produce fibre of short staple at the end of the rainy season. There is also the *narma*

or *manua* gossypium arboreum, with more fleshy and shiny leaves, and an improved sub-variety termed *radya*. These occupy the ground longer, and produce fibre of long staple in the hot season.

Hemp.—This crop is chiefly confined to the valleys and tracts bordering the Himalayas (Tarai), where it grows wild. In some places it will yield fibre worth extraction ; in others it will yield the intoxicant *charas*, the most noxious of all stimulants to the human constitution, when habitually used. Low-caste men alone will cultivate hemp. The varieties are not mentioned.

San.—The varieties of this leguminous broom, with rattling seed-pods, are not mentioned. Its fibre is used for ropes and string. It resembles *arhar* in appearance while growing.

Roselle Hemp.— This is a hibiscus, yielding a soft, whitish, silky fibre, used for sacking (*tāt*) or gunnybags ; also for cords for drawing water, *dol.* Its leaves are rather like hemp leaves.

NORTH-WEST PROVINCES.—*Value of Irrigated Crops in* 1882–83.

Ganges Canal in 1882–83.		Area.	Produce in lbs.	Value of produce.	Value of crop from one acre.
		Acres.	Lbs.	£	£
Sugar-cane		109 261	—	706 807	6·5
Garden produce, including orchards and water-nuts		9 007	—	59 466	6·6
Rice		30 531	26 070 080	151 486	5·0
Cereals.	Wheat	343 034	410 549 840	1 302 200	8·9
	Barley	75 148	80 295 200	182 700	2·4
	Maize	20 413	11 707 680	19 445	0·9
	Great Millet	2 047	1 202 080	3 718	1·8
	Common Millet (chena)	1 577	—	1 293	0·8
	Miscellaneous, including Bajra, Gojai, Bejhar, Mandwa and others	49 365	—	77 997	1·6
Pulses.	Common Gram ...	10 736	9 525 840	23 553	2·2
	Peas	16 636	—	25 120	1·6
	Miscellaneous, including Urad, Masur, and mixed crops	10 727	—	17 776	1·6
Oil-seeds.	Oil-seeds, 2; Miscellaneous, 138 ...	140	—	248	1·7
Fodder— Lucerne, Chari & Misc.		9 515	31 184 640	9 687	1·0
Fibres, Dyes and Drugs.	Cotton	22 966	—	68 898	3·1
	Flax	48	—	123	2·5
	Indigo	140 974	—	281 948	2·0
	Miscellaneous	1 084	—	2 472	2·3
	Opium	110	—	352	3·2
	Tobacco	174	—	783	4·6
Total ...		853 493	—	—	—
Insufficiently irrigated		2 542	—	—	—
		856 035		2 936 051	

BAHAR.—*Value of Crops per Acre* 1882–83.

On the Sohan Canal, 1882-83.		Area.	Produce.	Value.	Value of crop, from one acre.
		Acres.	Lbs.	£	£
Sugar-cane		18 653	46 424 960	120 506	6·2
Garden produce		13	53 600	86	5·4
Paddy		52 920	54 495 280	91 095	1·7
Cereals.	Wheat	8 887	9 322 720	25 051	2·9
	Barley	5 809	5 330 560	8 701	1·6
	Barley and wheat ...	157	125 600	262	1·6
	Barley and peas ...	2	1 600	3	1·5
	Oats	5	5 440	8	1·6
	Common Millet (chena)	22	22 160	55	2·5
Pulses.	Gram	13	12 400	21	1·5
	Peas	996	696 080	1 115	1·1
	Lentils	2	240	4	2·
	Rahar (Arhar?) ...	5	440	9	1·8
Oil-seeds	Mustard	4	2 880	14	3·5
	Linseed	43	20 160	95	2·2
	Castor nuts	4	2 560	9	2·2
Un-classified.	Khesari	12	11 520	19	1·6
	Murwa	10	15 200	22	2·2
	Burreah	5	3 600	11	2·2
Dyes, Drugs & Spices.	Indigo	362	2 880	760	2·1
	Safflower	25	3 920	28	1·1
	Opium...	1 065	22 720	22 223	20·9
Miscellaneous		31 710	29 593 440	54 352	1·7
Leases.	Five-year lease Kharif ...	35 106	28 279 120	41 410	1·2
	Five-year lease Rabi ...	11 581	5 627 200	9 887	0·9
	Five year lease Sugar-cane	6 290	10 097 040	28 266	4·5
Total... ...		173 701		404 012	

BAHAR.—*Plantations of the Sohan Canals in 1882.*

Name of Tree.	Eastern Sohan.	Arrah.	Baxar and Western.
	Number.	Number.	Number.
Babul	21 514	—	336
Bakain	4 110	2 085	320
Gumur	475	282	—
Gular	807	—	139
Jak	46	782	16
Jaman	1 477	1 465	1 584
Mango	2 925	2 161	598
Mohua	907	2 828	375
Nim	13 068	3 504	2 680
Pipal	1 008	613	309
Siris	13 839	14 993	1 145
Sissu	38 020	16 484	5 177
Tamarind	749	1 027	1 418
Tar	4 038	—	—
Teak	199	1 864	—
Tun	21 493	864	1 412
Others	11 594	6 260	545
Totals	136 269	55 302	17 123

Total in 1882 ... ... 208 694 | Total in 1881 ... 178 467

BENGAL.—*Crops and Plantations.*

The crops grown under the influence of the Midnapur Canal are almost entirely rice—the staple crop of Bengal; occasionally, perhaps a little *boro dhan*, or hot season rice, and some small cold weather crops may be raised. This being a region in which the annual rainfall ranges from 3 to 6 feet—average 4·5 feet—it became important to decide whether irrigation effected any increase of crop. Experiments on a large scale, extending over ten years, have proved that the advantage from irrigation is manifest, excepting in years of excessive rainfall; apart from the undoubted advantages of saving all the crops in seasons of drought and of irregular rainfall.

The following table illustrates the results of the experiments, as regards weight of produce; it is also possible that irrigated produce may be of better quality and command higher prices, but this is not stated. The weights are in maunds of uncertain value (80 tollahs?) and are hence not reduced to English weight. (The Imperial maund = 40 ser = 3 200 tola.)

BENGAL.—*Results of Yearly Experiments on Rice Crops.*

Under Midnapur Weir.	Rainfall.	Irrigation.	Experiments.		Weight of Outturn under Irrigation.		Weight of Outturn Unirrigated.		Percentage of Difference.	
			Irrigated.	Unirr.						
Year.	Inches.	Acres.	Number.	Number.	Paddy.	Straw.	Paddy.	Straw.	Paddy.	Straw.
1873	44·6	30 657	46	12	16·32	22·50	4·41	9·75	270	131
1874	57·5	60 866	287	85	12·86	42·48	11·28	32·87	14	29
1875	53·9	47 705	346	126	23·00	56·25	18·00	37·50	28	50
1876	70·9	28 724	185	148	18·56	45·00	18·74	43·22	nil.	nil.
1877	51·8	16 764	234	299	18·06	39·51	10·07	20·85	79	89
1878	53·4	50 834	351	163	23·24	61·40	15·32	31·30	51	96
1879	37·7	86 275	850	158	20·31	46·47	6·32	14·14	221	229
1880	57·9	91 690	636	291	22·00	59·00	[illegible]·00	52·00	10	13
1881	74·0	91 685	636	239	21·28	48·54	20·07	46·48	6	4
1882	62·8	88 532	883	249	19·75	44·50	16·40	40·70	20	9
Under Panchkurah Weir.										
1875	64·1	5 562	39	39	29·00	53·00	22·60	37·00	28	43
1876	69·1	2 774	26	26	31·22	85·52	29·42	76·03	6	12
1877	59·7	2 530	41	41	21·40	39·24	14·61	31·17	54	26
1878	43·0	6 019	111	82	33·43	60·17	28·62	54·03	16	11
1879	32·1	9 525	115	22	29·00	46·58	16·51	22·88	76	103
1880	56·5	10 917	95	22	31·00	64·00	27·00	59·00	15	8
1881	82·1	11 250	28	4	26·35	54·50	23·25	43·50	17	25
1882	47·7	9 729	38	16	2[illegible]·69	78·12	20·11	64·28	47	21

Value in 1882 :—Paddy, 15 to 18 pence per maund ; straw, 3 to 6 pence per maund.

Midnapur Canal.—The plantations chiefly consist of *bâbul*, coconut, rain tree, or jún, karunja, mango, and khiris; the extent of the plantations in 1882-83 was not large.

SOUTHERN INDIA.

THE WATERING OF CROPS IN ORISSA.

The Late Crops, watered between June 1 and December 1:—

	On ground from		On ground from
1. Sarud rice ...	April to Feb.	3. Laghu rice ...	May to Nov.
2. Biyali rice ...	May to Oct.		

The both Season Crops, requiring perennial watering:—

	On ground from		On ground from
1. Sugar-cane ...	April to Mar.	3. Yams	May to Feb.
2. Turmeric and ginger	June to Mar.	4. Brinjal ...	June to Jan.
		5. Pan and plantain	Whole year.

The Early Crops watered between December 1 and June 1:—

	On ground from		On ground from
1. Dalua rice ...	Feb. to May.	*6. Tobacco ...	Nov. to Apr.
*2. Wheat ...	Nov. to Mar.	*7. Coriander ...	Oct. to Feb.
*3. Barley ...	,, ,,	*8. Onions and garlic	Nov. to Jan.
*4. Gram and peas	,, ,,		
5. Achua cotton	Nov. to July.	9. Achua castor oil	Nov. to Feb.

The Dry Crops not requiring irrigation are:—

Late Crops.

1. Mandia.
2. Biri pulse.
3. Black kulthi.
4. Black mug.
5. Jute and hemp.
6. Haldiya cotton.
7. Haldiya castor oil.

Early Crops.

1. White kulthi.
2. White mug.
3. Harar chaitra.
4. Mustard.
5. Linseed.

Both Season Crops.

1. Harar nali.

*2. Til.

Pulses generally.

N.B.—The crops marked (*) are rarely cultivated.

The usual rotation of the dry crops is, 1st year, Biyali rice (which, like Laghu rice, can be grown without irrigation), followed by pulses, kulthi, mug, linseed, or mustard; 2nd year, cotton, turmeric, ginger, or sugar; 3rd year, fallow.

The country cotton is an annual; of oil seeds, castor oil is the only one that profits from irrigation; pulses and linseed suffer from rain; ginger and turmeric require only one or two waterings; sugar-cane is sometimes planted as early as February and cut in November. There is a rice of coarse species grown in swampy tracts called Boro dhan. The yield of Sarud rice, the staple crop, is said to be doubled by irrigation, and amounts to 10 cwt. per acre.

ORISSA.—*Value of Crops per Acre in* 1882–83.

On the Orissa Canal, 1882-83.		Area.	Value of Produce.	Value of Crop from one Acre.
		Acres.	£	£
Sugar-cane ...		398	10 045	25·2
Garden Produce.	Turmeric	55	839	15·2
	Garlic ...	5	28	5·6
	Brinjal	32	252	7·9
	Vegetables	16	48	3·
	Plantain	8	87	10·9
	Saru ...	50	206	4·1
	Pan ...	21	1 050	50·
	Supari (Nut)	1	133	133·
	Onion ...	36	450	12·5
	Chillies	3	15	5·
	Cucumber	2	6	3·
Wheat ...		1	1·5	1·5
Rice	Sarud and biyali	128 530	154 236	1·2
	Dalua ...	855	599	0·7
Pulses, &c.	Mug ...	115	230	2·0
	Mandia	2	1·4	0·7
	Chena ...	2	1·4	0·7
	Achu ...	1	1·0	1·
	Inker ...	14	14·	1·
Oil-seeds.	Mustard	7	16·	2·2
	Castor seed	81	324·	4·0
Indigo ...		133	133·	1·0
Cotton ...		2 660	18 354	6·9
Total ...		133 028	187 070	—

Orissa Canals.—The plantations chiefly consist of Date, Mulberry, Punang, Coconut, Betelnut, Palm, Kurranj, and Mango; the total of seedlings, saplings, and trees above 12 feet, being 122 519 in 1882.

Experiments in Watering Rice Crops in Orissa.
(*By* Mr. James Kimber, C.E.)

The Balagurriah Plot of 54·3 acres was irrigated by means of a shoot 1 foot square, and a field channel 700 feet long therefrom. The experiments were made in the year 1872, which had a total rainfall during the irrigation season of 53 inches. From the 7th to 14th July, 1872, the water ran with 0·5 foot depth in channel, and a head of 1 foot, the discharge of those seven days being 965 584 cubic feet or 1·58 cubic feet per second; gauge readings being made four times a day on each side of the field sluices. The readings, reduced and entered, were averaged to give a mean daily head; from this, the amount of opening, and the number of hours open, the daily discharge was calculated. The total results were thus:—

Total amount of water given	2 885 006	cub. ft.
Area irrigated	2 368 028	sq. ft.
Amount of water represented vertically	1·213	feet.
Number of hours irrigating	674	hours.
Duty during actual irrigation of 1 cub. ft. per sec.	46	acres.
Or actual duty on the area of 1·19 cub. ft. per sec.	54·3	acres.

A similar experiment was made on the Srimantapur plot, but in this instance nearly double the water actually needed was used in order to obtain as much silt as possible; this then gave a duty during actual irrigation of 1 cubic foot per second to 38 acres over forty-eight days.

In the former case, however, the irrigating period was 674 hours, or twenty-eight days. Now the works generally are designed to give the same quantity of water, but spread over 120 days, hence each cubic foot of water from the canal might be made to do $\frac{120}{28} = 4$ times the duty shown in the present experiment, and, taken this way, the duty capable of being effected would be $4 \times 46 = 184$ acres per cubic foot per second; or, taking an average of the two sets of experiments, of which the latter seems of little value in combination with the former, of 152 acres per cubic foot per second. But an average of this sort cannot so well be determined from an isolated plot as it could be from utilisation of the whole of the discharge of a completed distributary. The most useful result in this case was the absolute amount of water per acre taken from the channels, which was $\frac{2885006}{54} = 53\,406$ cubic feet in the first case, and very nearly double that in the second.

BARAR.—*The Unirrigated Crops.*
According to L. JACKSON, *Executive Engineer for Irrigation.*

Unirrigated Crops.	Usual date of sowing.	Shoots after.	Buds after.	Crop cut after.	Produce per acre, excluding straw, &c.	
The Jarayat Kharif, or early dry crops.		Days.	Days.	Days.	Average. lbs.	Max. lbs.
Cotton, Gossypium herbaceum	1 July	5	120	150	100	317
† *Jowari*, Holcus sorghum	10 July	7	120	150	300	630
† *Bajri*, Holcus spicatus	1 Aug.	4	90	105	300	450
Til, Sesamum orientale	29 Aug.	7	90	105	200	660
† Rice, Oriza sativa ...	Different	5	60	105	200	600
Ambari, Hemp, Hibiscus cannabinus	10 July	3	90	120	80	bundles
Baru, Flax	10 July	2	60	90	100	bundles
† *Bhadti*	10 July	5	60	75	120	
Muth Ph. aconitifolius...	10 July	5	90	105	80	
Holag	...	5	90	120	80	
* *Udidh*	10 July	7	90	105	240	
* *Mug*, Phaseolus mungo	10 July	4	105	120	300	
* *Tur*	...	5	90	120	180	
† Ginger, Zingiber officinale	July	12	700	1 000	1 100	
Red Pepper, Capsicum annuum.						
The Jarayat Rabi, or late dry crops.						
† Wheat, Triticum vulgare	22 Sep.	5	105	135	200	330
† Tobacco, Nicotiana tabacum	Sep.	8	90	150	200	480
Kardi	25 Sep.	5	90	135	120	
Lakh					160	
Gram, Cicer arietinum					160	
Juwas					80	
(Lentil) *Masur* ...	9 Oct.	5	105	135	80	
† *Vutanu*...					160	
Gadmol					80	

Rough data of increase of yield to the above crops by irrigation.

Jowari, one half more.	Rice, four times more.
Bajri, one quarter more.	Wheat, Gram, } one quarter more.
Til, one half more.	

* Supplementary crops, sown among others. † Crops that may be assisted by irrigation.

BARAR.—*The Irrigated Crops.*

According to L. JACKSON, *Executive Engineer for Irrigation.*

Baghayat or wet crops grown on land perpetually irrigated or kept damp by rain.	Usual date of sowing.	Shoots after.	Buds after.	Crop cut after.	Produce per acre, excluding straw, &c.	
		Days	Days	Days	Average. lbs.	Max. lbs.
Maize, Zea mays	...	5	75	105	100	—
Pepper, Capsicum perennium	1 July	7	105	370	2 000	—
Bengan or *Brinjal*, Solanum melonganum ...	"	7	120	370	4 000	—
Bhoimug, Phaseolus mungo	"	5	90	120	800	—
Ganja, Cannabis sativa ...	"	8	150	150	1 600	—
Onion, Allium cepa ...	25 Sept.	7	37	120	—	—
Garlic, Allium sativum ...	"	5	37	120	—	—
Methi, Trigonella fenugræcum	"	7	30	120	—	—
Carrots, Daucus carota ...	"	8	75	75	—	—
Kand, Batatas edulis ...	"	8	135	135	1 200	—
Opium, Papaver somniferum	1 Nov.	5	75	90	10	20
Sangmurla	"	5	75	90	—	—
Rajgura	"	5	90	120	240	—
Wheat, Triticum vulgare ...	"	5	105	120	300	—
Sugar-cane, Saccharum officinarum	March	12	300	300	1 600	7 500
Sang of Goor	"	7	37	75	—	—
Bhend, Abelmoschus esculentus	"	7	40	80	—	—
Karii	"	7	75	90	—	—
Turai (Cajanus indicus ?) ...	"	8	90	120	—	—
Kawala	"	5	90	120	—	—
Chawala	"	5	37	75	—	—
Plantain	23 May	3	360	450	400 trees.	
Betal, *Pan*, Piper betel ...	"	—	—	—	—	—
Fruit trees	"	—	—	—	—	—

THE WATERING OF CROPS IN BARAR.

1. The following crops are watered daily in the hot season, and at intervals of from one to seven days throughout the rest of the year as required: sugar-cane, pan, plantain, bengan, sag, bhaji, and green vegetable produce; when the sugar-cane is one foot high, the supply of water is reduced.

2. The following crops are watered once in three days in the hot season, and at intervals of from three to seven days throughout the rest of the year as required: ganja, opium, onions, garlic, perennial pepper, bhoimug, fenugreek, carrots, kand, chika, chakut, sangchawali, and the common produce of small vegetable gardens.

3. The following crops are watered once in three or four days at all seasons, generally: anise, saffron, turmeric, ginger, ratalu, goradu, pendia, wangi.

4. The following crops are irrigated once a week generally: sang of goor, bhend, karli, turai, kawala, chawala, sangmurla, and rajgura.

5. The remainder are: wheat, once in fifteen days; maize, three waterings to the crop; young fruit trees, once a week; older trees, four or five times a year.

The ordinary conditions of well-irrigation in Barár are thus:—

The wells have an average depth of 30 feet, and are each worked by one pair of bullocks for nine hours daily, which raise a leather bag (mot) containing 300 lbs. of water. They can thus water half an acre daily well, but for a continuance cannot keep watered more than 3 acres of ordinary irrigated crops. The prime cost of a common unreveted well is £30, the bullocks £15, gear £5, in all £50; the daily expenditure is, feed of bullocks 1s., labour of two men, at 1s. each, in all 3s.; or about £50 a year.

Produce of Crops at the Experimental Farms in Barár, 1870.

Yield of clean cotton in lbs. per acre.

	Umraoti	Sheagaon.		Umraoti	Sheagaon
Banni ...	184	86	Hinghanghat ...	180	56
Jarri ...	66	150	Dharwar ...	14	24

Manured land yielded 430 lbs. of clean cotton per acre.

The following were the yields of other crops: jowari, 538 lbs.; wheat, 745; gram, 312; muth, 300; linseed, 278; peas, 408 lbs. In ploughed land, jowari yielded 660 lbs.

The Irrigated Crops of the Bombay Presidency.

The Principal Crops Irrigated in 1882–83.

	Acres.
Wheat	6 617
Great Millet	2 561
Spiked Millet	2 341
Rice	1 947
Maize	108
Chino, Rala and Wara	111
Barley	131
Other cereals	221
Total	14 037
Ground Nut	3 633
Gram, Urad and Mug ...	2 817
Other Pulses	235
Total	6 685

	Acres.
Sugar-cane	5 011
Vegetables	768
Fodder and Lucerne ...	383
Fruit and other Trees ...	739
Other Garden Crops ...	60
Total	6 961
Condiments	599
Oil seeds...	27
Drugs	144
Sundries...	282
Total	41 052
Grand Total	28 735

The total depth of watering considered necessary is:—

For rice crop ...	4 months	... ...	1·5 feet
For sugar-cane ...	11 "	... ...	3·0 "

A good well will keep irrigated from four to six acres of inferior garden crop.

The Crops of the Madras Presidency and their Seasons.

	Local name.	Botanical Terms.	Sown in	Cut in
Cereals.	*Cholam* ...	Sorghum vulgare ...	September	December.
	Kambu ...	Penicillaria spicata ...	April ...	June.
	Tennai ...	Panicum italicum ...	September	January.
	Chamai ...	Panicum miliaceum ...	July ...	January.
	Godambai ...	Triticum vulgare ...	July ...	December.
	Makkai ...	Zea mais	July ...	October.
	**Nellu* ...	Oriza sativa	July ...	October.
	Kevaru ...	Eleusine coracana ...	June ...	October.
Pulses.	*Thovarai* ...	Cajanus indicus ...	July ...	April.
	Kadalai ...	Cicer arietinum ...	July ...	April
	Ulandu ...	Phaseolus aureus ...	July ...	February.
	Pacha payaru...	Phaseolus mungo ...	September	December.
	Pattani ...	Pisum arvense ...	September	December.
	Tulkapair ...	Phaseolus aconitifolius...	December	March.

	Local Name.	Botonical Terms.	Sown in	Cut in
Dyes and Drugs.	*Averi* ...	Indigofera tinctoria ...	November	March.
	Manjel ..	Curcuma longa ...	August ...	February.
	Inji ...	Zingiber officinale ...	September	February.
	Emburchai ...	Rubia cordifolia (Madder)	October...	February.
	Kusamba ...	Carthamus tinctorius ...	November	March.
	Kasakasa ...	Papaver somniferum ...	October...	March.
	Poghrielli ...	Nicotiana rustica ...	January...	April.
Fibres.	*Parati* ...	Gossypium herbaceum	May ...	January.
	Ganja (Hemp)	Cannabis sativa	Six months at any time.	
	Allivarai (Jute)	Corchorus capsularis		
	Allivarai (Flax)	Linum usitatissimum		
	Ianupanar ...	Crotalaria juncea ...	August ...	March.
	Pulchi ...	Hibiscus cannabinus ...	August ...	March.
Oil Seeds.	*Sittamunak* ...	Ricinus communis ...	August ...	November.
	Kadagu ...	Sinapis, three varieties ...	September	February.
	Yellu ...	Sesamum orientale ...	January ...	April.
	Katamilli ...	Coriandrum sativum ...	December	March.
Miscellaneous.	*Pusani kai* ...	Cucurbita maxima ...	July ...	December.
	Pudel ...	Tricosanthes cucumerina	July ...	December
	Kothaverai ...	Trigonella fœnugræcum	July ...	October.
	Picha kai ...	Cucurbita citrullus ...	February	April.
	Valleri ...	Cucumis sativus ...	April ...	July.
	Molam ...	Cucumis melo ...	April ...	July.
	Sathakupa ...	Anethum sowa ...	December	March.

* Many varieties of rice are grown in the Madras Presidency: one is a cold weather crop, and another is left a long time standing; but that above-mentioned is the staple crop, its period being coincident with the rainy season.

The Watering of Crops in the Madras Presidency.

The general allowance of water to rice crops in the Madras Presidency is 1 cubic foot per second of supply to 40 acres; to sugar-cane, gram, plantain, and garden crops, 1 cubic foot per second to 120 acres; ordinary field crops are rarely grown in places where irrigation is available.

WATER RATES AND TOLLS.

NORTH-WESTERN INDIA.

On the Bari Doab Canal, from 1862–63 to 1869–70.

	s.	d.
For all crops, per acre per crop ... 2r. 6a. 8p. or	4	10
Lift irrigation, one-half the above rate.		
Since 1869–70.		
I. Sugar-cane, per acre per year	12	0
II. Rice, per acre per crop ... ... Garden produce, per acre per half-year	9	6
III. Kharif crops. Cotton, hemp, indigo, turmeric, sesamum, waternuts, vegetables, orchards, fruit trees ... Rabbi crops. Wheat, barley, mixed grain, linseed, sarru, taramira, mustard, opium, tobacco, tukhmbalanga, safflower, chillies, vegetables, per acre per crop	5	0
IV. Kharif crops. All millets, maize, and crops not elsewhere mentioned ... ... Rabbi crops. All pulses, all grasses, fallow lands, and crops not elsewhere mentioned, per acre per crop	3	0
V. Single waterings, and Rabbi crops not requiring water after December, per acre per crop	1	6
For lift irrigation, one-half the above rates.		

Average supply per acre, 44 000 cubic feet.

On the Western Jamna Canal, from 1862–63 to 1866–67.

	s.	d.
On all first-class lands, per acre per crop	2	3½
On all second-class lands, per acre per crop	1	4
For lift irrigation, two-thirds the above rates.		

Since 1866–67 the rates have been identical with those of the Ganges and Eastern Jamna canals.

North-Eastern India.

On the Dehli and Gurgaon Irrigation Works, from 1862 to 1870, the rates were for grass crops, per acre, 5d.; and for all other crops, per acre, 9½d.

Ganges and Eastern Jamna Canals, from 1862–63 to 1865–66.

		s.	d.
I.	Sugar-cane, per acre per year	8	9½
II.	Fruit, nursery and vegetable gardens, all cultivated grasses, rice, waternuts, ajawen, and similar herbs, per acre per crop	5	0
III.	Indigo, cotton, tobacco, wheat and oats (rabbi), per acre per crop	3	4
IV.	Barley, all pulses and millets, maize, safflower, oil seeds (kharif), per acre per crop	2	5

From 1865–66 to 1867–68.

Gardens, and all lands taking a perennial supply, were transferred from Class II. to Class I.; and the rates then became for Class I., 10s.; II., 6s.; III., 4s. 6d.; IV., 3s. 4d.

Since 1867–68, the fruit, vegetable, and nursery garden produce have been transferred again into Class II., but the rates for the various classes have otherwise remained the same as before. For lift irrigation, the rates have always been two-thirds of those by flow.

The other sources of revenue are, for watering cattle, 12s. per 100, per year; sheep and goats, 4s.; supplying tanks, rent of corn mills, sale of grass, timber, fuel, and fruit, fines for trespass, &c.

Dun Canals, from 1862–63 to 1865–66.

For garden produce, sugar-cane, and first-class rice, 2s. 6d. per acre per crop; for tea, 1s. 3d.; for wheat and inferior rice, 1s.

From 1865–66 to 1867–68.

		per acre. s.	d.
I.	Tea, sugar-cane, garden, and perennial watering, per year	10	0
II.	First-class rice, tobacco, opium, and waternut, per crop	6	0
III.	Indigo and cotton ... ... „	4	6
IV.	Inferior rice, wheat, oats, and other crops ... „	2	6

From 1867–68 to 1871–72, tea and sugar-cane remained in Class I., the garden and orchard produce being transferred to Class II.; but the rates for the various classes remained unaltered.

Since 1871–72, the rate for tea has been altered to 1s. 6d. for each watering; leaving sugar-cane alone in Class I.; the rates for other produce on some of the Dun canals have been lowered

For lift irrigation, the rates have been always two-thirds of those by flow.

Rohilkand Canals.

		per acre. s.	d.
I.	Garden and orchard ... ... per crop	4	0
II.	Sugar-cane, tobacco, opium and waternut, per first watering	1	0
III.	All cereals, pulses, and oilseed ... " "	0	6

In Classes II. and III., half rates for every subsequent watering.

For lift irrigation, the rates are half of those for flow.

The number of waterings prescribed on the Naginah Canal is :—

For fruit gardens	per year	8	waterings.
Hemp	per crop	5	"
Rice, sugar-cane, indigo, tobacco, cultivated grasses and herbs ...	"	4	"
Cotton, cereals, and pulses ...	"	3	"

Bahar and Bengal.—The later rates are not specified in the returns available. For others *see Brief Accounts of Canals*.

Navigation Tolls in Northern India.

The Western Jamna Canal transit dues are tabulated according to a most complicated code, the rates for various sorts of timber varying from 1s. 3d. to £4 per score for the whole course of the canal, with a reduction for intermediate distances; the rates by weight being about 6d. per ton for the whole course of the canal.

The Bari Doab Canal transit dues are :—

For rafts of all sorts of timber ...	1½d. per £10 value at starting.
For rafts of bamboos	¾d. per thousand.
For rafts of firewood, hemp, flax, and grass...	⅛d. per 4 tons, or 100 maans.
For rafts of reeds, sirkanda ...	⅛d. per thousand bundles.

The Ganges Canal transit dues, since 1872, have been :—

		s.	d.
For boats, per month		9	0
Rafts of logs, per mile	per 100 cubic feet	0	$1\frac{1}{8}$
Rafts of sleepers, &c., per mile ...	„ „	0	$0\frac{1}{2}$
Rafts of bamboos, per mile	„ „	0	$0\frac{1}{4}$
Rafts of firewood, per mile	per 1 000 cubic feet	0	$0\frac{1}{2}$

The Eastern Jamna Canal is very little used for navigation.

SOUTHERN INDIA.

Orissa.—The water rates and tolls apparently have varied much from time to time ; it is difficult to discover them from the available returns. For earlier rates *see Brief Account of Canals.*

n the Bombay Presidency there is generally a combined land and irrigation assessment. The lands are divided into three sorts, and classified according to depth of soil, in cubits of 18 inches, and with respect to their special advantages and disadvantages. It is considered that no advantage arises from more than two cubits in depth of soil, as it cannot imbibe and retain more effective moisture; the disadvantages taken into consideration are the presence in the soil of kankar, coarse sand, loose or stiff soil, excess of moisture, and liability to be flooded. In a moist climate the better and worse descriptions of land are considered more on a par, the latter benefiting more from moisture than the former.

The general assessment, per acre, is as follows :—

	s.	d.		s.	d.
For unirrigated or dry crops	3	6			
For ordinary irrigated or garden crops	8	0			
For special irrigated crops in some places ...	14	0	to	30	0

The rates allowed on the Mukti project are : For sugar-cane, 56s. ; for rice, 20s. ; for wheat, 10s. per acre. And those allowed on the Lakh project and Bhatodi tank are :—

For perennial, or 12 months, irrigation ...	per acre	18s.
For wet and cold season, or 8 months, irrigation	„	10s.
For mansun, or 4 months' irrigation ...	„	6s.

In the Madras Presidency there is generally a combined land and irrigation assessment. The consolidated revenue, including the water rate, is two-fifths of the value of the produce, but is sometimes less, according to the market price of rice.

The general assessment per acre is as follows :—

	s.	d.		s.	d.
For unirrigated or dry crops	4	0			
For rice	9	6	to	16	0
Sugar, at the same ratio, would be sometimes as much as				120	0
But the general range of assessment is from	4	0	to	50	0
The water rate allowed by Government on the Tumbhaddra Canal of the Irrigation Company is ...	10	0	to	12	0
In Maisur, the general rate per acre is	12	0	to	15	0

On the Tumbhaddra Canal (also called the Karnul Canal).

Reduced rates introduced in 1882 :—	Flow. s.	Lift. s.
Single wet crop, per acre	8	6
Second wet crop on irrigated land	6	5
If compounded, for two crops for a term of not less than 5 years	12	9
Sugar-cane, betel and garden crops remaining o[illegible]und for time of two crops	12	9
Single dry crop	2	$1\frac{1}{2}$
Second dry crop on irrigated land	2	$1\frac{1}{2}$
Garden crops, of class 2 of old rates	6	$4\frac{1}{2}$

A reduction of 50 per cent. on these rates for the first five years, and of 25 per cent. for the second five years for lands not cultivated within the last ten years. For waste lands in blocks of 50 acres and more, free irrigation is given for 5 years, and at half rates for the second term of 5 years.

Basis of Water Rate.

Water rate should, if possible, be based on the difference between the value of a crop per acre and the cost of producing it ; but as land rent may be arbitrary, and wages and the value of produce may vary, that method may fail when an irrigation scheme comes into operation. A comparison with other works and rates in actual operation, therefore, forms a second basis, to which modification the observed local circumstances can be

applied. The statistics and statements of Anglo-Indian magistrates and tax collectors, &c., should not be trusted in such matters ; independent information is alone of any value.

When comparing the water rates in vogue in different parts of India, the average wages of a day labourer, or coolie, should be borne in mind. The following are approximate data :—

In Northern India	3d. to $4\frac{1}{2}$d.
In Barár	6d. to 9d.
In the Bombay Presidency ...	6d. to 9d.
In the Madras Presidency ...	$2\frac{1}{4}$d. to $3\frac{3}{4}$d.
In Maisur	3d. to 6d.

NORTH-WESTERN INDIA.—*Analysis of*

Constituents per Gallon.	1.	2.	3.
Place	Kabul, at Naushera.	Kabul, 1 mile above Naushera.	Kabul, near Fort Michni.
Date	May, 1868.	24 December, 1868.	January, 1870.
Total hardness	4·2	8·8	10·72
Permanent hardness	2·8	5·2	4·75
Grains of oxygen required per million grains	0·51	0·10	0·80
Ammonia	present	—	none
Phosphoric acid	traces	traces	trace
Nitrous acid	—	—	trace
Grains of nitric acid in 70 000	—	—	none
Total solids in 70 000 grains of filtered water	9·7	15·75	18·1
Volatile matter	0·45	·14	1·60
Mineral matter	9·25	15·61	16·5
Earthy salts, silica, oxide of iron, insoluble	5·07	—	11·2
Lime, as carbonate	3·46	—	3·75
Silica	—	—	present
Soluble salts	4·18	—	53 ?
Chloride of sodium	0·6	0·8	1·45
Sulphate of soda...	2·64	3·6	4·1
Carbonate of soda	1·56	—	—

1, 2, 7, 8, and 9, by Dr. Center; 4, 7, and 8, Dr. Sheppard; 3, 5

the Water of the Rivers of the Panjab.

4. Ravi, at Mian Mir? 16 December 1868.	5. Jhelam, 1½ miles below Rawalpindi. 10 May, 1869.	6. Satlaj, at Bhawalpur. 28 March, 1870.	7. Gaggar, at Mubarikpur. 21 December, 1867.	8. Gaggar, 8 miles from Amballa 28 November, 1868.	9. Harru, above Campbellpur. 13 October, 1867.
5·95	2·22	7·16	6·3	6·9	8·5
2·92	1·27	3·55	2·5	3·7	6·7
0·29	1·38	0·25	0·24	0·29	0·50
none	none	none	—	—	—
traces	none	traces	traces	traces	—
none	none	none	—	—	—
none	—	none	—	—	traces
11·70	7·7	11·85	15·2	15·48	17·4
0·64	0·7	0·40	0·34	0·7	1·2
10·06	7·0	11·45	14·88	14·78	16·2
8·79	Analysis unfinished.	6·15	10·9	9·7	—
4·70		4·40	8·4	6·3	—
0·80		0·75	—	0·88	—
2·27		5·30	3·8	5·07	—
0·32		1·20	0·42	0·75	0·42
1·47		3·30	2·6	2·23	—
—		0·95	1·3	2·5	0·6

Dr. Harvey; 6, Dr. Hutcheson. 2, river at its lowest.

NORTH-WESTERN INDIA.—*Analysis ot the Water of*

Constituents per Gallon.	1.	2.	3.
Place	Indus, at Attak.	Indus, at Attak.	Indus, at Dera Ismail Khan.
Date	23 June, 1868.	24 December, 1868.	28 April, 1869.
Total hardness	3·3	6·5	4·8
Permanent hardness	4·3	5·	2·5
Grains of oxygen required per million grains	0·51	0·16	0·69
Ammonia	—	—	none
Phosphoric acid	traces	—	none
Nitrous acid...	—	—	none
Grains of nitric acid in 70 000	—	traces	none
Total solids in 70 000 grains of filtered water	5·14	10·15	10·73
Volatile matter	0·35	0·42	0·81
Mineral matter	4·79	9·73	9·93
Earthy salts, silica, oxide of iron, insoluble	3·7	5·39	4·64
Lime, as carbonate...	3·0	—	3·04
Silica	0·3	—	unk.
Soluble salts	1·19	4·34	5·29
Chloride of sodium...	0·21	0·42	1·31
Sulphate of soda	1·3	2·6	1·35
Carbonate of soda	0·72	1·4	0·24

1, 2, 4 and 5, by Dr. Center; 3, Dr. Thomson;
1, water rising rapidly, nearly

he Water of the Rivers of the Panjab.

3. Indus, t Dera Ismail Khan. 28 April, 1869.	4. Harru, 1½ miles above Saidan Baoli. 24 November, 1868.	5. Leh, above Rawalpindi. 25 September, 1869.	6. Swat, near Abazai. January, 1870.	7. Tovey, 2 miles above Kohat. 2 October, 1870.	8. Kurram, 5 miles from Bannu. 14 November, 1870.	9. Bainganga, 1½ miles above Kargra. 11 May, 1870.
4·8	9·63	8·7	6·6	15·9	8·81	3·1
2·5	6·7	4·7	2·2	8·27	7·11	2·04
0·69	0·19	0·39	0·24	0·19	0·28	0·59
none	—	traces	trace	none	none	none
none	—	present	trace	none	none	none
none	—	present	none	none	none	none
none	0·5	traces	none	none	—	—
10·73	17·8	19·5	10·45	29·4	16·8	5·6
0·81	0·3	1·5	1·4	1·26	1·4	0·7
9·93	17·5	18·	9·05	28·14	15·4	4·9
4·64	—	14·	7·25	14·14	7·	2·8
3·04	11·1	8·6	4·5	9·8	5·46	1·61
unk.	—	2·31	traces	0·98	trace	—
5·29	—	4·	1·8	14·	8·4	2·1
1·31	0·49	0·63	0·45	2·52	1·68	1·05
1·35	—	0·8	1·4	4·36	2·16	traces
0·24	—	0·9	0·27	3·8	3·78	0·76

. Thomson; 6, Dr. Harvey, 7, 8, and 9, Dr. Whitwell.
idly, nearly at its height; 2, river at its lowest.

NORTH-EASTERN INDIA.—*Analysis of the*

Constituents per Gallon.		1	2.	3.
	Place	Near Allahabad.	Above Danapur.	Below Khanpur.
	Date	April, 1867.	25 May.	May, 1867.
Total hardness		5·8	6·	4·3
Permanent hardness		2·5	3·25	3·5
Grains of oxygen required per million grains ...		0·62	·016?	7·3
Ammonia		present	—	present
Phosphoric acid		abund.	present	abund.
Nitrous acid...		—	—	o
Grains of nitric acid in 70 000		—	traces	o
Total solids in 70 000 grains of filtered water ...		11·9	10·9	11·06
Volatile matter		3·5	1·05	2·52
Mineral matter		8·4	9·85	8 54
Earthy salts, silica, oxide of iron, insoluble ...		4·06	6·8	5·25
Lime, as carbonate		2·9	6·7	2·52
Silica		—	traces	traces
Soluble salts...		4·34	3·05	3·29
Chloride of sodium		1·05	1·05	0·8
Sulphate of soda		1·5	2·88	1·54
Carbonate of soda		2·0	1·07	0·9

1 and 3, by Dr. Milne; 2 and 4, Dr. Jameson; 5 and 6, Dr. Compigne;
The Ganges is believed to supply

—Analysis of the Water of the Ganges and its Tributaries.

3. Below Khanpur. May, 1867.	4. Below the Sohan, at Danapur. 4 Oct., 1867.	5. At Allahabad. 21 Oct., 1867.	6. At Khanpur. 14 Nov., 1867.	7. At Fattahgarh. 1 May. 1869.	8. ¼ mile above Chunar. 11 Sept., 1869.	9. Bhagaratti, opposite Barhampur. 28 Oct., 1867.	10. The Sohan, at Danapur. 6 Oct., 1868.
4·3	5·8	8·26	4·5	3·7	7·0	5·35	3·5
3·5	3·9	3·2	3·2	1·8	3·1	2·73	2·8
7·3	·035 ?	0·48	0·4	0·7	0·45	1·07	0·61
present	—	—	0	none	traces	—	traces
abund.	—	—	0	none	none	traces	traces
0	—	—	0	none	none	—	traces
0	—	—	0	none	none	—	under 1 gr.
11·06	14·3	8·4	9·2	9·1	8·75	13·05	10·22
2·52	2·3	0·7	0·51	1·75	1·4	1·26	3·01
8 54	12·1	7·7	8·69	7·35	7·35	11·79	7·21
5·25	7·0	5·25	7·4	4·37	6·65	8·9	5·25
2·52	5·1	3·15	?	3·29	4·9	3·7	3·78
traces	traces	—	—	0·7	traces	3·15	1·68
3·29	5·1	2·45	1·29	2·97	0·7	2·8	1·96
0·8	1·26	1·05	0·42	1·05	0·74	0·63	0·42
1·54	2·34	?	?	1·92	traces	0·4	0·45
0·9	1·5	0·47	0·76	—	0·76	0·8	0·44

r. Compigne; 7 and 8, Dr. Whitwell; 9, Dr. Thomson; 10, Dr. May

ved to supply the best river water in India.

NORTH-EASTERN INDIA.—*Analysis of the Water of the Jamna*

Constituents per Gallon. Place / Date	1. Jamna, above Dehli. 28 Sept., 1866.	2. Jamna, 2 miles above Agra. 14 Dec., 1866.	3. Jamna, above Agra. 25 April, 1867.	4. Jamna, opposite Allahabad. April, 1867.
Total hardness	4·45	6·7	3·9	8·8
Permanent hardness	2·86	2·95	1·0	4·6
Grains of oxygen required per million grains	0·05	0·35	0·48	0·72
Ammonia	—	—	—	—
Phosphoric acid	—	—	present	traces
Nitrous acid...	—	—	—	present
Grains of nitric acid in 70 000	—	—	—	—
Total solids in 70 000 grains of filtered water	11·64	14·8	16·8	21·0
Volatile matter	0·72	1·2	2·8	3·5
Mineral matter	10·92	13·16	13·3	17·5
Earthy salts, silica, oxide of iron, insoluble	8·62	7·64	5·53	9·1
Lime, as carbonate	3·73	6·4	unknown	4·27
Silica	0·58	traces	—	—
Soluble salts	2·29	5·96	7·77	8·9
Chloride of sodium	0·84	1·44	2·1	4·4
Sulphate of soda	1·15	1·6	unknown	3·6
Carbonate of soda	—	0·86	unknown	4·2

1 and 5, by Dr. Sheppard; 2, Dr. Jameson; 3, Dr. Cameron; 4, Dr. Milne; The Jamna water is invariably reported

and of Southern affluents of the Ganges.

5. Jamna, above Dehli. 17 May, 1867.	6. Jamna, at Allahabad 23 Oct., 1867.	7. Jamna, $1\frac{1}{2}$ miles below Matthra. 26 June, 1868.	8. Morar, 1 mile below town. 26 Sept. 1867.	9. Morar, above bend. 18 July, 1868?	10. Morar, above bend. 13 August, 1868?	11. Morar, 3 miles above Morar-Bazar. 7 February, 1870.	12. Umram, above Nagod. 3 April, 1868.	13 Betwa, 5 miles from Jhansi. 14 Nov. 1867.
4·7	8·78	4·1	5·1	5·9	5·4	7·7	13·3	3·4
3·95	2·36	2·0	0·9	0·6	1·2	5·0	2·4	1·7
0·06	0·60	0·26	0·6	0·36	0·21	0·46	0·59	0·22
0	—	—	—	present	—	none	—	—
0	—	—	present	present	present	none	—	trace
0	—	—	trace	present	—	none	—	—
0	—	—	0·5	trace	—	none	—	—
10·04	11·2	13·3	10·3	15·54	9·8	15·75	18·9	9·8
0·34	0·35	0·8	1·2	1·3	1·3	0·91	1·9	1·0
9·7	10·85	12·5	9·1	14·24	8·5	14·84	17·0	8·8
7·16	7·91	7·6	4·9	—	5·0	8·4	10·0	4·7
4·9	6·5	4·2	3·2	6·0	3·3	5·74	8·8	2·8
0·63	—	traces	traces	2·13	—	2·1	0·42	—
3·54	2·94	4·9	4·2	—	3·5	6·44	7·0	4·1
0·72	1·6	1·37	1·2	3·01	1·5	1·47	1·7	1·15
2·8	?	2·0	—	0·47	1·6	5·11	1·9	—
1·6	0·95	1·8	1·3	2·03	—	traces	3·0	1·14

6, Dr. Compigne; 7, 8, 9, 10, 13, Dr. May; 11, Dr. Whitwell; 12, Dr. Thomson. to be excellent everywhere.

NORTH-EASTERN INDIA.—*Analysis of the Water*

Constituents per Gallon.	1.	2.	3.	4.	5.
Place	Gumti, above Lakhnau.	Gumti, at Lakhnau.	Gogra, 1½ miles above Faizabad.	Gogra, 1½ miles above Faizabad.	Sai, 2 miles below Rai Bareli.
Date	22 April, 1867.	26 December, 1868.	16 June, 1867.	11 June, 1861.	27 April, 1868.
Total hardness	4·8	4·7	4·5	4·2	8·0
Permanent hardness ...	2·09	2·0	2·6	2·7	3·2
Grains of oxygen required per million grains ...	0·11	0·11	0·08	—	0·1
Ammonia	0	0	—	—	—
Phosphoric acid ...	0	0	—	—	—
Nitrous acid	0	0	—	—	—
Grains of nitric acid in 70 000	0	trace	—	—	traces
Total solids in 70 000 grs. of filtered water ...	15·4	14·0	11·2	10·85	16·8
Volatile matter	1·4	1·05	0·84	0·7	1·4
Mineral matter	0·14	12·95	10·36	10·15	15·4
Earthy salts, silica, oxide of iron, insoluble ...	9·52	8·57	8·2	8·75	4·9
Lime, as carbonate ...	7·0	8·05	5·0	8·05	4·2
Silica	trace	0	—	traces	0·21
Soluble salts	4·48	4·37	2·16	1·4	10·5
Chloride of sodium ...	1·4	0·63	1·7	0·63	6·3
Sulphate of soda ...	trace	0·58	traces	traces	1·9
Carbonate of soda ...	2·28	2·28	0·6	0·48	1·3

1, 2, 3, 4, 5, 6, 7, 8, by Dr. Orton;
4, very good; 7, indifferent

is of the Water of the Northern Affluents of the Ganges.

5. Sai, 2 miles below Rai Bareli. 27 April, 1868.	6. Sai, opposite Rai Bareli. 26 April, 1868.	7. Surain, at Sitapur. 8 April, 1868.	8. Surain, at Sitapur. 16 January, 1869.	9. Kurnaut, 1 mile above Shahjahanpur. 27 May, 1869.	10. Garrah, 3 miles above Shahjahanpur. 3 June, 1869.	11. Ramganga, at Bareli. 6 July, 1869.	12. Ramganga, ½ mile above Muradabad. 27 July, 1869.	13. Ganguir, 4 miles above Muradabad. 29 July, 1869.
8·0	8·02	7·2	6·7	8·53	10·28	3·9	3·25	4·4
3·2	3·2	4·2	3·8	2·54	5·2	2·36	3·15	2·9
0·1	0·2	—	0·15	2·0	0·85	0·35	0·4	0·3
—	—	traces	trace	—	—	none	none	none
—	—	—	none	—	—	none	none	none
—	—	—	none	—	—	none	none	none
traces	freely present	present	inappr.	—	none	none	none	none
16·8	15·4	17·0	16·1	18·76	17·67	14·87	18·37	14·0
1·4	1·75	2·0	1·4	1·96	1·93	2·21	1·75	0·87
15·4	13·65	15·0	14·7	16·8	15·75	12·67	16·63	13·13
4·9	4·9	10·8	11·2	12·42	8·75	9·27	14·7	11·03
4·2	4·2	9·9	10·85	6·83	5·69	5·07	7·0	49·55
0·21	0·18	0·3	trace	3·5	2·27	3·5	5·25	4·9
10·5	8·75	4·2	3·5	4·37	7·0	3·39	1·93	2·1
6·3	5·2	0·8	0·75	1·26	1·05	0·74	0·63	0·74
1·9	1·6	2·2	1·48	2·89	11·23	7·69	3·53	3·53
1·3	1·9	1·4	1·24	3·52	3·43	nil	0·57	1·23

by Dr. Orton; 9, 10, 11, 12, and 13, Dr. Whitwell.

7, indifferent water, after a heavy rainfall.

NORTH-WESTERN AND NORTH-EASTERN INDIA.—

Constituents per Gallon.		1.	2.	3.	4.
	Place	Canal from the Ganges, below Khanpur.	Canal from the Ganges, above Khanpur.	Canal from the Ganges, 3 miles above Aligarh.	Ganges Canal, below Rurkhi Aqueduct.
	Date	April, 1867.	11 November 1867.	-3 August, 1869.	1 April, 1870.
Total hardness		4·35	4·7	3·2	2·14
Permanent hardness		2·86	2·8	3·2	1·31
Grains of oxygen required per million grains		0·3	0·65	0·45	0·23
Ammonia		present	0	none	—
Phosphoric acid		large	0	none	none
Nitrous acid		traces	0	none	none
Grains of nitric acid in 70 000		0	0	none	none
Total solids in 70 000 grains of filtered water		6·8	8·26	8·93	5·6
Volatile matters		0·72	0·7	0·87	0·7
Mineral matters		7·35	7·56	8·05	4·9
Earthy salts, silica, oxide of iron, insoluble		5·67	5·07	5·78	—
Lime, as carbonate...		3·71	2·6	3·71	2·1
Silica		traces	—	2·45	traces
Soluble salts		1·6	2·5	2·27	—
Chloride of sodium...		1·2	1·5	0·53	1·12
Sulphate of soda		1·28	?	2·98	none
Carbonate of soda		0·33	?	0·66	none

1, by Dr. Milne; 2, Dr. Compigne; 3 and 11, Dr. Whitwell; 4, 5, 6, 7 and 8,

Analysis of the Water of various Canals.

Canals of the Dera Dun.				9.	10.	11.
5. Main, 2 miles above Dera. 27 December, 1869.	6. Branch. 7 January, 1870.	7. Reservoir Branch. 11 January, 1870.	8. Branch, ½ mile above Gurka Lines. 2 February, 1870.	Canal from the Ravi, at Mian Mir. 16 December, 1868.	Canal from the Barra, above Peshawar. 19 May, 1867.	Canal from the Kurram, near Fort of Bannu. 17 November, 1870.
18·1	18·63	18·42	18·32	5·2	7·63	7·9
11·94	11·00	11·77	11·27	3·7	3·45	6·9
0·14	0·15	0·29	0·24	0·25	0·83	0·54
none	none	none	none	none	present	present
none	none	none	none	traces	traces	none
none	none	none	none	none	present	present
traces	traces	traces	traces	none	—	—
52·7	—	53·1	59·92	9·40	12·84	22·4
0·4	—	0·6	0·42	0·48	2·68	1·4
52·3	—	52·5	59·5	8·92	10·16	0·21
22·4	—	—	—	5·97	6·16	10·5
18·7	17·59	18·4	22·68	6·24	unknown	6·58
3·3	present	0·9	traces	0·4	0·6	1·36
29·9	—	—	—	2·95	4·0	10·5
0·3	1·39	2·8	2·5	0·56	0·53	1·68
21·67	28·4	24·95	28·78	2·52	1·3	5·04
1·36	—	—	3·29	—	0·13	3·03

Dr. May; 9 Dr. Sheppard; 10, Dr. Center; 4, contains no iron.

Results of Analysis of Waters from various Tanks.

By the Chemical Analyser to the Government of Bombay, in 1884.

Place and Name of Tank.	Month.	Grains per Gallon. Total Solids.	Chlorine.	Parts per Million of Ammonia. Free.	Albu-menoid.	Quality.	Sediment.
Nasirabad, Storage tank ...	July	58·8	17·5	0·01	0·13	Bad	Scanty.
Ajmir { Ana Sagar Lake ..	June	74·2	22·4	1·38	1·80	,,	Algæ and paramecia.
Ajmir { Do. filtered ...	,,	76·3	22·1	0·58	1·70	,,	Paramecia.
Ajmir { Rewari	July	39·2	9·7	6·82	1·50	,,	Many algæ.
Guzrat { Kháraghoda ...	Jan.	49·0	22·1	0·21	1·04	,,	Algæ and paramecia.
Guzrat { Do.	May	111·3	55·3	0·72	0·82	,,	—
Ahmadabad, Filter Tank ...	June	37·1	7·4	0·03	0·31	,,	Protozoa.
Nasik, Trimbak Kushawarta	Sep.	21·0	2·0	1·33	1·26	,,	Numerous algæ.
Bombay, Butcher's Island...	Aug.	5·6	0·1	0·32	0·52	,,	Algæ and paramecia.
Kolaba { Diu	May	50·4	6·4	0·05	0·18	,,	Protozoa.
Kolaba { Wadan	,,	49·0	15·8	0·59	0·48	,,	Protozoa.
Kolaba { Shahabag	Aug.	15·4	5·3	0·08	0·62	,,	Algæ and rotifera.
Haidarabad, Dakhan { Davircherru ...	Dec.	23·1	1·7	0·05	0·36	,,	Rather abundant vegetable débris, diatoms, and a few paramecia.
Husen Sagar ...	,,	13·3	1·4	0·21	0·32	,,	
Ibrampatan Ch. ...	,,	19·6	1·4	0·09	0·45	,,	
Patel: tank ...	,,	19·6	1·4	0·13	0·19	Good	
Kutwa ...	,,	19·6	1·1	0·13	0·20	,,	
Mir Alam ..	,,	22·4	1·1	0·08	0·32	Bad	
Mir Jhare Hauz	,,	19·6	1·1	0·01	0·32	,,	
Túka Hauz ...	,,	21·0	1·4	0·05	0·40	,,	

From another Series by the Chemical Examiner, Panjab, 1882.

Ajmir, &c. { Abu Lake	—	11·0	1·5	0·16	0·19	—	—
Ajmir, &c. { Ana Sagar Lake ...	Nov.	11·9	2·1	0·40	0·5[illegible]	[illegible]	[illegible] paramecia, rotifera.
Calcutta, Dr. Warden's tank	—	11·3	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]rown re[illegible], blackening muc[illegible] on ignition.
Dum-Dum, Digla	Jan.	10·2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]ellowish, s[illegible]ght blackening.
Dacca, Manikganj	Apr.	7·3	[illegible]	0·06	[illegible]	[illegible]	Do. do.
Howrah, Hadua	Sep.	59·6	9·5	0·40	0·54	—	Decaying vegetable tissue no e[illegible]matozoa.
Nagpur, Ambajari	Jan.	7·0	0·7	0·00	0·16	Good	Protozoa.
Bombay, Vehar	Mar.	6·3	0·6	0·01	0·24	,,	—

RESULT OF ANALYSIS OF THE AVERAGE WELL WATERS OF STATIONS IN NORTHERN INDIA, ACCORDING TO VARIOUS ANALYSTS.

Situation.	Date of Examination.	Grains per Gallon, or parts in 70000.			Oxygen required per million parts.	Character and Remarks.
		Total Solids.	Volatile Matter.	Chlorides.		
NORTH-WESTERN INDIA.—						
Peshawar ...	May, 1868	27·4	2·7	2·0	0·50	Indifferent.
Naushera ...	May, 1868	18·2	0·98	0·8	0·27	Verywholesome.
Attak	May, 1868	123·3	3·8	28·0	—	Very bad.
Rawalpindi ...	Sep. 1867	28·9	3·5	0·6	0·51	Pure and good.
Mian Mir ...	Dec. 1868	59·3	1·4	3·3	0·63	Very bad.
Amritsar ...	Dec. 1869	56·2	6·1	15 6	—	Good.
D. Ismail Khan	Apr. 1868	37·2	1·5	5·8	0·47	Fair.
D. Ghazi Khan	Mar. 1869	42·7	1·8	8·7	0·62	Fair.
NORTH-EASTERN INDIA.—						
Dehli	—	75·0	7·8	unk.	—	Very bad.
Matthra ...	Dec. 1867	39·6	2·0	10·8	0·51	Fair.
Agra	Jan. 1868	45·4	4·1	11·2	0·47	Bad.
Jhansi	Nov. 1867	25·1	4·9	2·4	0·53	Wholesome.
Murar	Aug. 1868	29·6	2·1	5·7	0·51	Bad.
Faizabad ...	Jan. 1867	18·6	1·3	1·8	0·17	Good.
Fattahgarh ...	Apr. 1869	34·3	2·2	4·6	0 54	Doubtful.
Aligarh ...	Aug. 1869	35·1	2·6	5·7	0·44	Very foul.
Allahabad ...	Mar. 1860	33·1	1·1	3·9	—	Fair, but hard.
Banaras ...	Dec. 1868	25 9	1·3	2·8	—	Good.
Chunar ...	Sep. 1869	34·8	1·4	4·3	—	Hard and bad.
Danapur ...	Sep. 1868	59·2	5·5	10·3	0·31	Very bad.
Barhampur ...	Nov. 1867	31·1	2·3	8·7	—	Bad.

North-Western India.

Peshawar.—The drinking water is obtained by open canal from the river Barra, which also fills reservoirs; the water is excellent, but sometimes muddy; the reservoirs are frequently drained, but contain frogs, also Typha angustifolia, Potamogeitons and Confervæ.

The Peshawar Marsh being specially renowned for its malarious effects, an account of the flora that thrive there, will therefore be of interest. On the higher ground, which is covered with saline efflorescence, grow several species of Salsolaceæ, Franknia pulverulenta, Tamarix, Salix Babilonica. The ordinary plants that grow in and around the marsh are:—Epilobium occasional; Lycopus, abundant in parts; Lippia nodiflora and Herpetis monneira, about ditches; Utricularia, rare; Eclipta erecta, not uncommon; Ranunculus aquatilis and Ranunculus sceleratus, common; Limnanthemum cristatum, a species of Lium; Typha angustifolia, abundant; Nelumbium, cultivated; Butomus, rare; Sagittaria sagittafolia, Alisma equisetum, two species of Juncus, rare. Of Sedges, the following are common:—Cypicus exaltatus, Cypicus mucronatus, Malacochæte pectinata, Scupus maritimus, Catix Wallichiana, Eleocharis palustris. The common grasses about and near the water are:—Agrostis alba, Polypagon monspeliensis, Andropogon Bradlii, Cynodon dactylon, an Arundo, a Saccharum. The following are the floating and submerged plants:—A Ceratophyllum (demersum?), Potamogeiton crispus, P. pusillus, Potamogeiton plantageneus, rare; Hydrilla verticillata, Marsilia quadrifolia, Chara, most abundant; Nitella, occasional; Confervæ, profuse. Two species of Riccia, a Semno, and an Argola, are abundant in some places.

Haidarabad in Sind.—The wells are supplied by inundation from the Indus. The water is said to be soft, good, and wholesome, a few wells only brackish: yet the wells swarm with animal life. Like most wells in Sind, they may be exhausted by an ordinary Persian wheel in twelve hou.

Nasirabad.—Most of the wells are so salt that they are unfit for use. The water from the same well varies considerably in saltness, being sometimes palatable, clear and hard; that from a wholesome well was found to contain, after evaporation to dryness, organic matter in the large proportion of 1 in 200, as well as chloride of sodium and sulphates of alumina and potass, besides other chlorides and sulphates.

Disa.—Well water clear, agreeable, devoid of smell, almost free from organic matter, with an inconsiderable amount of aline or mineral ingredients.

Ahmadabad.—The well water, after long use, is apt to induce disease of the spleen, which the river water does not; the former has a higher specific gravity than the latter.

AVERAGE WELL WATERS OF STATIONS IN SOUTHERN INDIA (*according to old accounts*).

Baroda.—Well water clear, soft, and of good quality; it contains no sulphates, phosphates, or nitrates, nor any salts of lime; it is alkaline; it contains principally chloride of sodium; also carbonate of soda, and a faint trace of lime, but no iron.

Surat.—There is not a single well of fair drinking water within the station. All are impregnated with sulphuretted hydrogen.

Dhulia.—Well water good, soft, devoid of smell, of an agreeable taste, but of a rather blue colour.

Malligauni.—The wells require clearing from sediment once a year, and would otherwise become unwholesome.

Bombay.—Well water brackish, containing a large quantity of lime, also sea salt. Vahar reservoir water is considered pure.

Serur.—Well water hard, but good and wholesome; it contains a little lime.

Satara.—Wells and tanks in trap rock; the guinea-worm is found in them.

Sholapur.—Wells supplied by percolation from the tanks; water very good, soft, pure, uninjurious, and colourless; when filtered has a specific gravity of 1000·4 and contains 30 grains of solid matter to a gallon: under microscopic examination was found to contain no organic matter beyond a little shiny film. The tanks contain Flosaquæ, as well as ordinary grasses and rushes, and among the infusoria the encapsuled amalæ oscillatoria, and ædogonium; in dry weather, when the floss decomposes, the malaria is most noxious.

Ratnagiri.—Well water very good, as soft as rainwater, and free from taste or smell.

Belgaum.—Well water clear, good, soft, wholesome, and free from taste and smell. It contains chlorides, sulphates of lime and magnesia, and a salt of iron.

Dharwar.—The well water has the reputation of being very good and wholesome, but also of giving rise to guinea-worm among the natives.

RESULTS OF ANALYSIS OF THE AVERAGE WELL WATERS OF STATIONS IN SOUTHERN INDIA AND BRITISH BURMAH.

(By Drs. Harvey, Hastings, Sinclair, and Nicholson.)

Station.	No. of Wells examined.	Date of Examination in 1871 or 1872.	Total Solids per 100 000	Nitric Acid per 100 000	Hardness.	Character.
Kattak ...	13	Oct. '72	40 to 100	unkn.	15° to 20°	Very salt.
Jabalpur ...	—	May, 1868	30	unkn.	unkn.	Wholesome
Kamthi ...	6	Oct. to Nov. '72	40 to 70	2 to 6	15° to 20°	Fair.
Sitabaldi ...	2	Nov. & Dec. 72	30 to 40	1 to 4	7° to 27°	Fair.
Sikandarabad	27	Jan. to July, '72	31 to 90	1 to 4	12° to 30°	Bad.
MADRAS PRESIDENCY.						
Ballari	16	Feb. to Apr.'72	30 to 100	0·1 to 10	15° to 40°	Bad.
St. Thos. M'nt.	12	Aug. to Oct.'71	30 to 100	0·1 to 0·2	15° to 20°	Good.
Palaveram ...	8	Mar. to May,'71	50	Under 1	15°	Good.
Punamalli ...	6	Nov. & Dec.'71	30 to 70	Under 1	6° to 15°	Pure.
Vizagapatam	19	May to June,'72	50 to 200	1 to 15	20° to 40°	Salt.
Vizianagram	8	July, '72	50 to 100	unkn.	25° to 80°	Indifferent.
Barhampur ...	7	Sept. '72	25 to 50	1 to 2	8° to 20°	Indifferent.
Bangalur ...	77	During '71	20 to 200		Variable	Bad.
Kannanur ...	25	Feb. to Apr.'72	15	0·2 to 0·5	2° to 4°	Very good.
Trichinopalli	32	June to Sep.'72	15 to 100	0·3 to 0·5	10° to 20°	Indifferent.
Mangalur ...	4	Nov. '72	10	unkn.	4° to 8°	Good.
Quilon ...	3	Dec. '72	22	unkn.	2° to 5°	Good.
Palamkatta ...	3	Dec. '72	20 to 30	1	10°	Good.
Vellur	1	Dec. '72	56	unkn.	14°	Fair.
BURMAH.						
Thayatmyo ...	30	Dec.'71 to Feb.'72	50 to 100	1 to 2	20°	Safe.
Tonghu ...	26	June to Sep.'72	15 to 30	0·3 to 1·5	2° to 5°	Bad.
Mulmein ...	14	Nov. & Dec.'72	5 to 10	0·0 to 0·1	2° to 7°	Good.
Shwayghin ...	4	Nov. & Dec.'72	3 to 4	0·2 to 0·5	1 to 1·5	Good.

ANALYSIS OF THE WELL WATERS OF MADRAS, *by Dr. Wyndo ve* (*Averages for each Police Division of the Town*).

	1st Division.	2nd Division.	3rd Division.	4th Division.	5th Division.	Seven Wells.
No. of Wells	5	8	9	14	10	10
Appearance	Clear	Clear	Clear	Clear to turbid	Various	Clear
Odour	None	None	None	None	None	Various
Taste	None	Slightly brackish	Agreeable	Various	Various	Do.
Reaction to Test-paper	Neutral	Alkaline	Faintly alkaline	Acid	Do.	Acid
Hardness, temporary	2 to $5\frac{1}{2}$	2 to 13	3 to $8\frac{1}{2}$	$\frac{1}{2}$ to 7	$\frac{1}{2}$ to 6	2 to 35
Do. permanent	14 to 16	7 to 25	9 to 18	5 to 20	$7\frac{1}{2}$ to 16	6 to 17
Solid Ingredients in one Imperial Gallon.						
Organic, in Grains	3 to 5	3 to 9	4 to 9	2 to 6	2 to 8	4 to 8
Inorganic, Do.	60 to 79	27 to 242	24 to 48	10 to 61	10 to 48	19 to 64
Chlorides, Do.	40 to 60	7 to 180	10 to 24	4 to 38	3 to 29	4 to 26
Bases in Solution by Carbolic Acid.						
Iron	Average	Average	Average	Above	Average	Traces
Lime	Do.	Do.	Do.	Large	Do.	Average
Magnesia	Do.	Do.	Do.	Average	Traces	Do.
In Solution after Boiling.						
Lime	Large	Large	Fair	Average	Fair	Various
Magnesia	Average	Do.	Large	Above	Average	Do.
Chlorides	Very large	Do.	Do.	Large	Small	Not determined
Sulphates	Large	Do.	Rather large	Do.	Fair	Large
Nitrates	None	None	None	None	Not too abundant	None

N.B.—The well water of Madras is believed to be as bad as possible.

Analysis of Soils, Efflorescences, &c.

Analysis of a Specimen of "Reh" or Natron.

By Dr. Thomas Anderson, *Agricultural Chemist, on May 29th*, 1863.

Water	7·40	Brought forward	37·88
Organic matter	6·61	Peroxide of iron	3·30
Alumina	2·52	Alumina	1·95
Oxide of iron	trace	Lime	1·84
Lime	1·09	Magnesia	0·98
Magnesia	0·51	Phosphoric acid	trace
Potash	1·84	Silica	54·56
Soda	1·44	Soluble in acids	62·53
Chloride of sodium	10·41	Total	100·41
Sulphuric acid	6·06		
Soluble in water	37·88		

The remedy for "reh" proposed by Dr. Anderson, was under-drainage, irrigation, and washing out the soluble matters from the soil, in accordance with the views of Mr. Smith. The remedy for "reh" proposed by the Chemical Examiner of Lahor, Mr. J. E. Brown, is the old native remedy at Lahor of applying "shora," or "shora kullur," slightly modified. He proposes the artificial production of nitrate of lime in manure heaps, and a similar application to the soil.

Dr. J. C. Whishaw, of Faizabad, and Dr. J. White, of Sitapur, trace the production of "reh" to the formation of kankar (nodular limestone) in the soil, during which action carbonate of soda is liberated; but state that when the kankar is formed, the action would not necessarily continue. Dr. White's remedy is a proposal to make embanked canals watertight, and thus to prevent the percolation under pressure that is favourable to the production of "reh;" also to use manure and bone dust.

It was afterwards discovered that there were very many varieties of "reh:" in some sulphate of soda predominated; in others the carbonate of soda; in others, the chloride of sodium; and in others, nitrate of potash; but in none is only one salt found in a pure state.

ANALYSIS OF A SAMPLE OF "REH."

By PROFESSOR DUPRÉ, *received November*, 1863.

Soda	22·59	Brought forward ...	60·61
Potash	2·65	Carbonic acid	16·00
Lime	0·16	Sulphuric acid	4·01
Magnesia...	0·30	Chloride	0·79
Alumina	0·26	Oxide of iron	1·08
Silica and Sand	34·65	Water	17·61
	60·61	Total...	100·10

Of these 44·03 are soluble in water.

ANALYSES OF THREE SAMPLES OF USAR SOIL FROM AUDH.

By MR. A TWEEN, *at Calcutta, August 14th*, 1863.

	(1)	(2)	(3)
Silica insoluble	66·16	67·66	62·2
Alumina insoluble	13·50	15·85	20·31
Alumina	2·55	3·36	3·47
Oxide of iron	2·16	2·14	4·33
Lime	0·81	0·39	0·65
Magnesia...	trace	0·28	trace
Alkali	2·85	1·01	0·09
Chlorine	0·54	0·14	0·06
Sulphuric acid	1·01	0·24	0·53
Phosphoric acid	trace	trace	0·00
Nitric acid	0·00	0·00	trace
Water	4·05	3·55	3·84
Organic matter	4·01	4·85	3·36
	100·	100·	100·

The alkali in all three cases is almost entirely soda; under "insoluble alumina" is included whatever of iron, lime, alkali, &c., is present in the insoluble clay. The samples were:—(1) An usar allowing no vegetation whatever; soft and slippery in the rainy season, swelling up and efflorescent in the hot season. (2) An usar growing scanty grass in the rains, which withers entirely in the hot season. (3) An usar allowing no vegetation whatever; it is extremely hard, water does not penetrate it to any depth; it becomes slippery in the rains. All samples were taken at 1 foot deep in the soil. The "sujjimitti" of Bengal is said to correspond with the usar soil of Audh, according to Prof. O'Shaughnessy

ANALYSIS OF SAMPLES OF REGUR (*Black Cotton Soil*).
By MR. TWEEN, *Mem. G.S.I., IV. p.* 361.

	(1) Near Seoni.		(2) Near Seoni.		Indor.	Barwani	Burhanpúr.
	At Surface.	5 feet below Surface.	At Surface.	3 feet below Surface.	At a few inches below surface.		
Insoluble ...	62·7	47·6	62·8	63·7	68·6	57·9	61·8
Organic matter ...	9·2	8·4	9·0	8·7	7·2	8·7	7·7
Water	8·4	7·6	8·2	6·5	9·4	9·9	7·4
Oxide of iron ...	11·0	15·9	10·9	11·4	6·8	4·4	5·7
Alumina ...	7·5	8·6	7·6	8·4	5·8	8·8	7·7
Carbonate of lime	1·2	11·9	1·5	1·3	1·6	9·3	8·5
Sulphuric acid ...	trace	—	trace	trace	—	—	—

Residue, chiefly magnesia and alkali, present in all cases.

According to Christie, Regur will absorb 8 per cent. of moisture by weight.

Note.—Seoni and Barwani are in the Narbadda Valley; Burhanpúr is in the Tapti Valley.

Some of the Regur plains have produced crops for 2 000 years without manure, fallow, or irrigation; but these are also in parts having a moderate annual rainfall, not exceeding 4 ft. Regur is the best soil for grasses and cereals; but there are also infertile Regur soils.

ANALYSIS OF IRON-CLAY OF HIGH-LEVEL LATERITE FROM RANGUN.
(*A highly ferruginous variety, free from sand grains.*)

Soluble in Acids.	Peroxide of iron ...	46·279
	Alumina	5·783
	Lime	0·742
	Magnesia	0·090
	Silica	0·120
Insoluble in Acids.	Silica dissolved by potash...	6·72
	Silica by fusion ...	30·728
	Lime, iron and alumina ...	2·728
	Combined water, alkalies and loss	6·802
		100·000

Note.—The percentage of peroxide of iron, soluble in acids, in nine Indian specimens of laterite, varied between 21·0 and 50·0.

LISTS

OF

GEOLOGICAL FORMATIONS AND GROUPS

IN THE

THREE DIVISIONS OF INDIA.

DEDUCED FROM "MEDLICOTT & BLANFORD'S MANUAL, 1879"

(*See also Indian River Basins*, pp. 242—246).

North-Western India.			List of Formations and Groups.
	Recent and Pleistocene		Blown sand, soils, and lake deposits. Rann of Kachh. Alluvial deposits of rivers, estuaries, and coasts. Sub-Himalayan high-level gravel.
Kainozoic.	*Supra-cretaceous.*	Pliocene.	Upper Manchhars of Sind. Miliolite of Katiawar. Upper and Middle Siwaliks of Salt Range and Sub-Himalayas. Mammaliferous beds of Western Thibet and Himalayas. Pliocenes of Kachh.
		Miocene.	Lower Manchhars and Gáj of Sind. Marri beds of the Panjab. Miocenes of Kachh.
		Upper Eocene.	Nari group of Sind; Kasauli and Dagshai beds.
		Middle Eocene.	Kirthar group of Sind; Sabathu beds (nummulitic). Nummulitic limestone of Sind and Panjab, Kachh and Guzrat. Indus or Shingo beds of West Thibet.
		Lower Eocene.	Ranikot beds of Sind. Lower Nummulitics of Salt Range, Kachh, and Guzrat.
Mesozoic.	*Cretaceous.*	Upper.	Coarse sandstones of Sind, under a thin trappean flow. Olive shales of Salt Range.
		Middle.	Hippuritic limestone of Sind. Cretaceous beds of Hazara and of Kohat. Chikkim beds of Spiti and Khoten.
		Lower.	Chicháli beds of the Salt Range. Neocomian beds of Kachh.
	Jurassic.	Upper.	Umia and Katrol beds of Kachh and Katiawar. Upper beds in the Salt Range. Jesalmir limestones. Gieumal sandstones and Spiti beds.
		Middle.	Middle variegated beds of Salt Range. Chari and Pachham beds of Kachh. Spiti shales of N.W. Himalayas.
		Lias.	Upper Tagling limestone of N.W. Himalayas.
	Triassic.	Upper.	Lower Tagling limestone of N.W. Himalayas. Para limestone of N.W. Himalayas. Nerinœa and Megalodon beds of Sirbán Hazara.
		Middle.	Salt Range, Liláng beds of Kashmir Zanskár and Spiti.
		Lower.	Keratite beds of Salt Range, Infra Triassic of Hazara.
Palæozoic.	*Permian and Carboniferous*		Carboniferous limestone of Salt Range. Krol limestone of Pir Panjal. Blaini beds. Krol and Infra Krol limestones of W. Himalayas. Kuling series of Kashmir and N.W. Himalayas.
	Silurian		Obolus beds of Salt Range. Attak Slates. Slate and traps of Pir Panjal and Kashmir. Muth and Bhabeh series of N.W. Himalayas.
Azoic.	*Vindhyan*		Upper Vindhyans in Malwa and Jodhpur.
	Transition, &c.		Salt marl of Salt Range. Arvalli transition beds. Maláni felsites (Balmir), Nagar Parkar volcanic group.
	Gneissic		Gneiss of Pir Panjal and Ladak (Syenitic). Upper Gneiss of Zanskar Range. Arvalli Gneiss. Lower or Central micaceous Gneiss of Himalayas.

NORTH-EASTERN INDIA. LIST OF FORMATIONS AND GROUPS.

	Recent and Pleistocene.	Blown sand, soils, and alluvial deposits. Kankar. Detrital laterite of Bhagalpur and Bengal. Khadir of Gangetic basin. Bhangar of Gangetic basin. Sub-Himalayan high-level gravel.
KAINOZOIC.	*Pliocene.*	Dehing group of Assam. Mammaliferous beds of Himalayas. Upper and middle Siwaliks of Sub-Himalayas.
	Miocene.	Tipam group of Assam. Náhan group of Lower Himalayas (Siwaliks) continued in Garhwal and Kumaon, also in Nipal (Churiaghati). High-level laterite of Bandalkhand and of Bhagalpur.
	Upper Eocene.	Kasauli and Dagshai beds of Sirmur group.
	Middle Eocene.	Sirmur group. Nummulites of Garo Hills (Assam). Coal measures of Assam.
	Lower Eocene.	Apparently wanting.
MESOZOIC.	*Cretaceous.*	Disang group of Assam. Upper cretaceous of Khasi Hills. Sandstones and Shales of Garo and Jaintiah hills. Local coal basins also.
	Traps.	Lower traps and Intertrappeans, near Sirguja, and in Malwa.
	Jurassic.	Rajmahal beds of the Upper Gondwana series. Dubrajpur beds. Mahadeva beds and Jabalpur beds in the valleys of the Sohan and the Damuda. Silhet trap (perhaps cotemporary with Rajmahal trap).
	Triassic.	Apparently non-existent in the Eastern Himalayas or in Assam.
PALÆOZOIC.	*Damuda.*	Panchet group of Raniganj and the Damuda Valley. Damuda beds of Sikkim and Bhutan. Damudas of Raniganj, Ironstone shales. Barakar, Karharbari and Talchir groups from Rajmahal to the Satpuras.
	Permian.	Infra Krol shales of Mansuri. Krol beds in Sirmur. Blaini and Infra Blaini slates of Simla. Silurian Fossiliferous beds in the north of Kumaon.
AZOIC.	*Vindhyan.*	†Upper Vindhyan beds of Bhanrae, Rewah, Kaimur, and Malwa. †Lower Vindhyan beds of the Sohan and Ken valleys. Semri beds.
	Transition.	Upper Transition rocks of Gwaliar. Bijawar series of Bandalkhand. Shillong series of Assam. Transition rocks of Bahar. The Arvalli (Transition). Champanir beds. (Transition). Lakhiserai and Shekpura Conglomerates.
	Gneissic.	Gneiss of Bahar, Rewah, and Chutia Nagpur. Dome Gneiss of Bengal. Gneiss of Assam. (Syenitic lower Gneiss.) Central micaceous Gneiss of the Himalayas. Darjiling Gneiss. Bandalkhand Gneiss, and Arvalli Gneiss.

† † The age of the Vindhyans and Transition rocks is unknown.

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SOUTHERN INDIA. LIST OF FORMATIONS AND GROUPS.

	Recent and Pleistocene.	Blown sand, soils, regur, &c. Recent alluvial deposits. Raised shell-beds of Coast. Low-level laterite. Older alluvial deposits. Cave deposits.
KAINOZOIC.	*Supracretaceous.*	Pliocenes of Surát and Baroch. Miocenes of Surát and Baroch. Ratnagiri plant beds. Eocences (iron-clay) of Surát. Travankur and Kollam limestones and lignites, sands, and clays. East Coast or Gudalur sandstones. High-level laterite.
MESOZOIC.	*Dakhan Traps of Cretacean Period.*	Upper Dakhan traps, and Upper Intertrappeans of Bombay. Middle Dakhan traps. Lower Dakhan traps, and Intertrappeans of Nagpur, the Narbada Valley, of Rajamahendri, Barár, and Mekalgandi. Lameta group of Infratrappeans. Rajamahendri Infratrappeans.
	Marine Cretaceous.	Arialúr group (near Tanjor and Pondicherry). Trichinopalli group. Utatúr group (near Trichinopalli). Bagh beds of the Lower Narbada Valley.
	Marine Jurassic.	Ellor beds. Tirupatti sandstones. Ragavapuram shales.
	Upper Gondwana Series of Jurassic Period.	Jabalpur group. Kotamaleri group (on the Pranhita). Sripermatur and Sattavedu group. Ongole plant-beds. Rajmahal beds occurring at Atgarh (Kattak) and Golapilli (Ellor) Mahadeva series at Bagra, Denwa, and Pachmarhi. Almod beds of the Southern Pachmarhis. Dubrajpur beds.
PALÆOZOIC.	*Damuda Series or Lower Gondwana.*	Kamthi group of the Godavari; Bijori group of the Sátpuras. Hengir group in Orissa; Motur group of the Sátpuras. Barákar beds in the Mahanadi, Narbada, and Godávri valleys. Talchir beds in the Brahmini Valley.
AZOIC.	*Vindhyan.*	Lower Vindhyan beds of the Karnul series. Pálnad limestone. Bhima limestones and shales. Penganga sandstones. Chattisgarh and Sambalpur sandstones.
	Transition.	Upper transition beds of Kadapah; Papagni, Cheyer, and Nallamale groups. Upper transition beds of Kaladgi. Krishna group. Bijawar beds in the Dhár forest, Bagh and Jobat. Lower transition beds of Manbhum Singbhum, and the Garhjat States.
	Gneissic.	Gneiss of the Arvalli type, near Bagh in the Narbada Valley. Main Gneiss of Southern India, (pink hornblendic). Granitoid Gneiss of the South Mahratta country. Granitic Gneiss of Orissa.

CEYLON.

DISTRICTS AND RIVERS.

CANALS AND TANKS.

RESTORED WORKS.

CEYLON.

Districts and Rivers.

The Districts of Ceylon in February, 1881 :—

District.	Area, sq. miles.	Population.
Northern.		
Jaffna	875	265 583
Mannar	432	21 348
Mulaittivu	927	7 638
Vavuniyan	937	7 931
Western.		
Nuwara Kaliawiya	2 547	44 146
Puttalam	1 184	78 154
Kurunegala ...	1 840	215 173
Negombo	248	116 691
Colombo	541	389 788
Kegalla	651	105 874
Ratnapura	1 434	119 955
Kalutara	581	165 021

District.	Area, sq. miles.	Population.
Southern.		
Galle	537	209 680
Matara	548	151 923
Hambantota ...	895	71 917
Eastern.		
Battikaloa ...	2 595	105 358
Trinkomalli ...	1 062	22 197
Tamankaduwa ...	1 500	22 000
Central.		
Kandy	904	288 332
Matale	982	86 655
Badulla	3 790	165 692
Nuwara Eliya ...	353	98 682

The whole area is given at 24 700 square miles, and the population was 2 850 000; there are 4 000 square miles of mountainous country, 3 000 to 7 000 feet above mean sea-level. The four central districts comprise 6 000 square miles.

The rivers of Ceylon are mostly unnavigable; the following are the names of the chief rivers :—

Rivers.	Catchment, sq. miles.
Flowing North.	
Kana Karayan Aru	—
Flowing West.	
Arivi Aru	1 100
Kala Oya	1 000
Mi Oya	—
Deduru Oya	—
Maha Oya	800
Kelani Ganga	1 300
Kalu Ganga	800
Bentota Ganga	—

Rivers.	Catchment, sq. miles.
Flowing South.	
Gin Ganga	—
Nilwala Ganga	—
Walawe Ganga	1 000
Magama Ganga	—
Kataragam Ganga	—
Flowing East.	
Kumukkan Aru	—
Patipal Aru	700
Mundini Aru	—
Maruru Oya	—
Mahaweli Ganga	4 300
(And an unnamed Horowapotane River.)	

The annual rainfall varies between 2·7 feet at Mannar to 18·7 feet at Padupolla; the day rainfall as a maximum is 9 to 12 inches, but occasionally 18 inches.

The mean daily evaporation at Colombo was 0·212 inch, and the mean humidity of the air was 75.

The depth of water necessary for a rice crop varies in parts of the island from 12 inches to 18 inches; but even this may be reduced in some parts, allowing for timely rain. If two crops are grown in the year, a depth of 24 to 36 inches is necessary.

Ancient Tanks and Canals.

The early Sinhalese kings of Seren Dip, to whom some of the larger works are ascribed, lived at the following dates :—

Panduvassa, 504 B.C., second king of Ceylon.

Dvenipia Tissa, 307 B.C.

(Name not given)—104 B.C.

Maha Sen, A.D. 66.

Tissa, A.D. 201.

Maha Sen, A.D. 275.

Dhatu Sena, A.D. 460, makes the Yodi Ela Canal.

Dappula, A.D. 795.

Wijey Bahu I., A.D. 1071, restores many of the works.

Prakrama Bahu I., A.D. 1153, makes the Ellehara Canal.

These works consisted in numerous tanks, as well as a few canals with weir off-takes from rivers; most kings made 15 to 30 tanks; Prakrama made 1 407, and repaired 1 395. Even in 1867, after centuries of neglect, there remained 4 903 tanks in Ceylon in various stages of disrepair; and these could hardly represent more than 10 per cent. of the original number, either large or small.

The larger works were evidently intended to supply water and irrigation near the two capital towns, Anuradha Pura and Pollunawara, in the now North Central Province, or in the old districts of Nuwara Kaliawiya and Tamankaduwa.

Whole districts in other parts were, however, irrigated for corn growing, as Ponpurrippu, "the golden plains," a district in the North-West Province, and the Seven Korles, or "granary of the Kandian Kings." The districts of Mannar, in the extreme north, as well as those in the extreme south, were well supplied with irrigation.

Some of the works were very large, and some showed engineering skill; but most of the works were village tanks, and it is very probable (judging from analogy of the tanks visited in Southern India) that some of them could never have been of much use at any time.

It is very difficult to trace the general design and even the localities of the larger works with the aid of books and maps; for the reasons that they are not technically described by qualified persons, that the names of the same places are given differently by different writers, and that the same names apply sometimes to different places.

The Kala Oya Series.—On the upper part of the River Kala Oya was the large tank, or enlarged lake, called Kala Weva, or Kalabalulu Weva, having a catchment of about 120 square miles, and 10 square miles in area; its dam is $5\frac{1}{2}$ miles long, 20 feet top breadth, and 50 to 60 feet high. It is still in good order, except at the breached waste weir, where the Kala Oya flows out. The Kala Weva tank was made in A.D. 460. From it there appears to have been two or three old canals.

1st. The Yodi Ela, 53 miles long and 40 feet wide, to the capital Anuradhapura, which supplied three large tanks: the Tissaweva, the Bassawakulam, and the Bulankulam.

2nd. The Jaya Ganga Canal, also leading from it to Anuradhapura, made in A.D. 1153, and probably supplying tanks near the former.

3rd. There is also a Pandaweva tank on the Kalamunu Oya, covering 1 400 acres. This may be either the same river or a branch of it; and the tank itself may be subsidiary to the Bassawakulam tank, which was made by Panduvassa, the same king, about 504 B.C.

This completes the series; but it must be noticed that the three large tanks before mentioned were probably made at different times, and the series was not complete until A.D. 1153.

The Amban Ganga Series.—On the upper part of the Amban Ganga a branch of the Mahaweli Ganga, was the Ellehara dam The dependent works are:—

1. A canal from Ellehara dam to Kondrowawe, 24 miles long, consisting of a series of lagoons, formed by a long earthen

dam, 40 to 90 feet high; and continuation of canal for five miles in cutting to Minery Lake.

2. A canal from Minery Lake to Kanthalay tank (also called Gantalawe, and, perhaps, also Kandela, and Kandely), 28 miles.

3. A dam on the Kara Ganga (another branch of the Mahaweli Ganga?) near Matale; and a canal from it to the Minery Lake.

4. The Kaalinde Canal from the Minery Lake, going northward. The Minery Lake, near the capital Pollunawara, and the Kanthalay tank, were made and improved at various times.

There is not any account available of any third complete series of ancient irrigation works. The other large tanks appear to be detached, and independent. They are :—

Detached large Tanks.—1. The Padivil tank, in the northern province, perhaps also called the Padawiya Lake, covering 15 square miles; dam 11 miles long, 30 feet wide at the top and 200 at the bottom, faced with large squared stone; built, probably, A.D. 66. Still in ruins.

2. The Topaweva tank in Tamankaduwa district; built about A.D. 307.

3. The Battikaloa tank, in the district of the same name, in the Eastern Province.

4. The Oorobokke dam, near Galle, in the Galle district.

5. The Tissa Maharama tank, near Hambantot, in the Southern Province. In the same province a tank, mentioned as the Tissaweva, near Kattregam Temple, built 307 B.C., may or may not be the same.

6. The Kalaa tank is mentioned as a very large tank in old native records; perhaps there are no traces of it now.

Modern Navigable Canals.

During the occupation of Ceylon by the Hollanders, A.D. 1656, to 1797, 120 miles of navigable canal were made; these, probably, were entirely round the backwaters of the coast between Galle and Colombo; details of these works are not forthcoming. They were entirely neglected by the British until recent times, when they were repaired, and 47 miles more were made.

Works of Restoration.

The credit of the initiation of the undertaking is due to Sir Henry Ward, Governor of the Colony, from 1855 to 1860.

Of village tanks in the North Central Province, which is a new combination of the two districts Müwara Kaliawiya and Tamankaduwa, 117 were repaired between 1874 and 1881, at an expense of £25 799 labour, besides valued at £38 741.

The expenditure on irrigation works completed, restored and improved between 1868 and 1881 (excluding village tanks) was thus :—

Province.		Expenditure. £	Irrigable Area in Acres.
Northern	1	1 081	200
North Central	3	17 637*	2 300
Central	8	8 953	7 730
North-Western...	9	22 030	5 460
Western	12	3 757	1 577
Eastern	22	81 094	57 070
Southern	24	78 372	15 731
Total ...	79	212 923	90 068

Other Works.

		£	
Bassawakulam tank	for water supply	6 071	
Vavuniya Velankulam	for water supply	1 081	
Yodi Ela Canal (in progress)		54 550 ...	25 000 acres.

Total Expenditure on irrigation works in Ceylon from 1868 to 1881	£ 332 038
Less recoveries by water rate and sale of land...	67 534
	£ 264 504

Future Works.

The old works in the *Northern Province* are being surveyed with a view to restoration.

In the Eastern Province, the anicuts of Pattamputti, and the Irakkaman tank and channel are in progress.

In the North-west Province, the next proposed restoration is the Pandáweva tank on the Kalamuna Oya, surface 1 400 acres, eventual irrigation 2 500 acres.

* This includes expenditure on 13½ miles of Yodi Ela Channel (of which the head works and 40 miles remain).

In the Southern Province, the next restoration is the Tissamaharama tank, near Hambantot, in progress.

The designs of most of the restoration works were made in Ceylon, at the office of Major Woodward.

It appears that some failures were made in the works of restoration, more especially at the Oorobokke dam, near Galle, in the Southern Province, and at the Battikaloa tank in the Eastern Province. There is no doubt that for works of this class experienced hydraulic engineers are absolutely necessary, and even with them works may fail from causes beyond their control.

As the author's personal experience in Ceylon was short and confined to sketching and snipe-shooting, the information above given is due to others; chiefly to the paper read by Mr. J. R. Mosse, at St. James's Hall on 13th May, 1884, and to two books on Ceylon by Mr. John Ferguson, Newspaper Editor, written in 1878 and 1884.

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